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THE INSTITUTION OF PRODUCTION ENGINEERS

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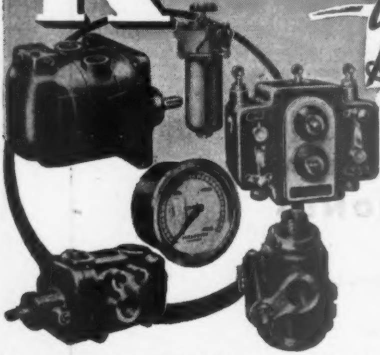

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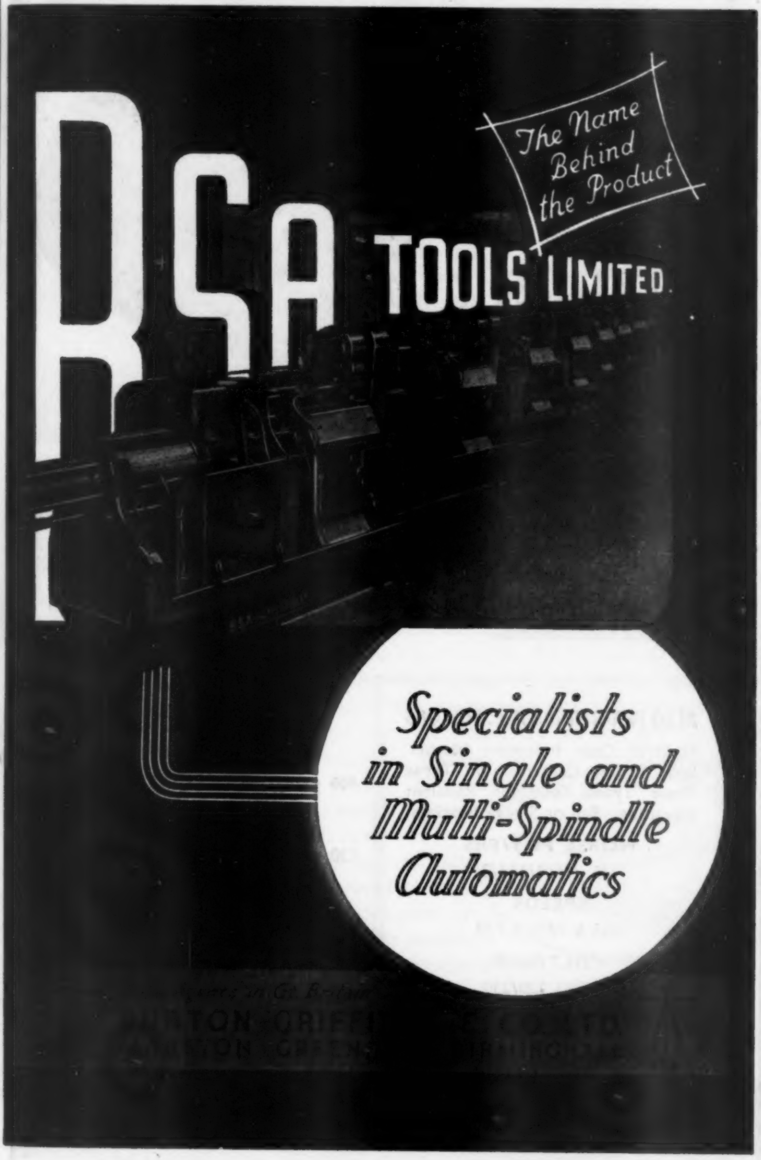
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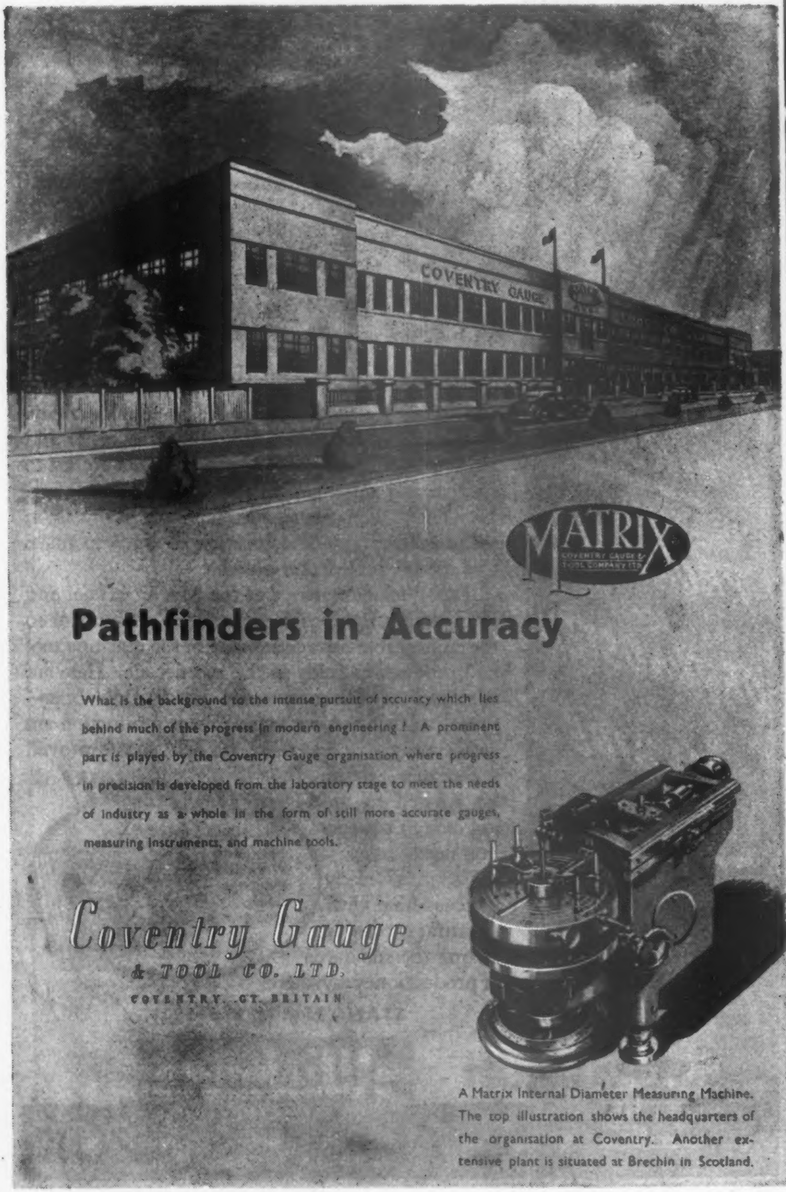

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HONORARY MEMBERS OF THE INSTITUTION

The Council has for some time past conferred on those who have rendered the Institution long and distinguished service the title of Honorary Member.

At the present time, the Honorary Members of the Institution are:

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Dr. G. Schlesinger.

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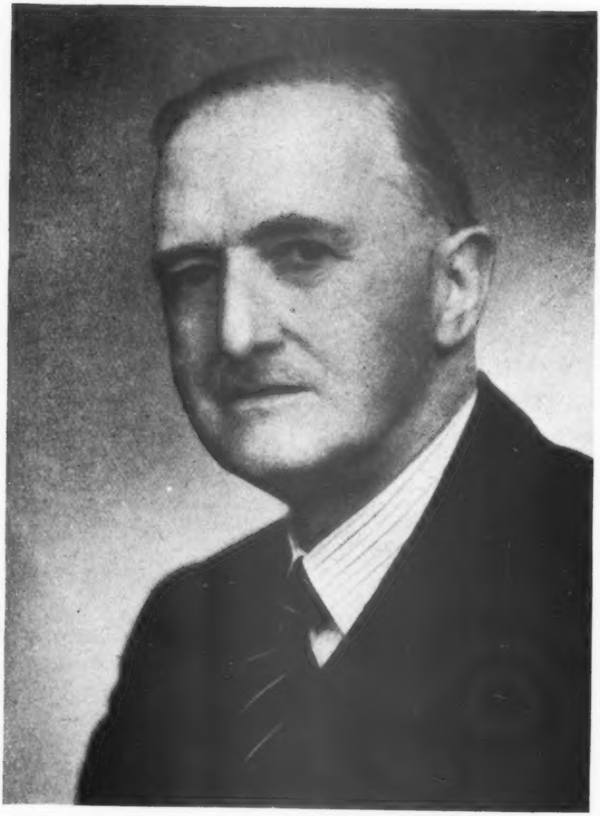
North Eastern . .	G. Robinson, 188, Westgate Road, Newcastle.
Wolverhampton . .	L. C. Jones, 1, Merridale Lane, Wolverhampton Staffs.
Yorkshire	W. R. Walton, 256, Belle Isle Road, Leeds, 10.

THE LATE MR. H. A. HARTLEY, M.I.P.E.



THE LATE MR. H. A. HARTLEY, M.I.P.E.

By the death of Mr. Herbert Anderson Hartley, M.I.P.E., the Institution has lost one of its most prominent members and a valued friend. Mr. Hartley was a man who was imbued with the true spirit of public service. His aim was to serve others and in this respect he was ready and willing at all times to expend what might have been his leisure hours in trying to improve the lot of his fellow citizens. He was a man of unquestionable integrity and never influenced by selfish motives, and his fine example will be long remembered as an inspiration to his fellow members.

From the time he joined the Institution in 1932 until his death, he gave his services unsparingly in an endeavour to improve the technique of production engineering. He played a major part in the formation of the Eastern Counties Section, and was elected its President in 1933. In this capacity he first became a Member of Council, subsequently filling the office of Chairman during the difficult years of 1942/44, after which he was elected a Vice-President. He remained a Member of Council until his death.

Upon the formation of the Standards Committee in 1934, Mr. Hartley was elected its first Chairman, and represented the Institution on the Mechanical Industries Committee of the British Standards Institution until 1947.

In recognition of his outstanding services to the Institution, he was elected an Honorary Member in April, 1948.

At the time of his death, Mr. Hartley was Chairman of Reavell and Company, Ltd., Ipswich, whom he joined in 1903 as Works Manager, being appointed to the Board of Directors in 1908. Prior to this, on completing his apprenticeship in 1897, he spent some time studying in Germany, and on his return to this country became assistant to the late Mr. Houston Stewart, M.I.C.E. In 1899 he was appointed Assistant Works Manager to Ruston Proctor Ltd. (now Ruston and Hornsby, Ltd.), where he remained until joining Reavell and Company.

In addition to his many business and Institution activities, Mr. Hartley was deeply interested in the work of educational and religious organisations in the Ipswich area, where he was held in the highest esteem. He was Chairman of the Governors of Culford School for 16 years, a member of the Ipswich Education Committee, and Chairman of the Ipswich Charity Commissioners.

As a local reacher for 54 years, he had held every office open to laymen in the Ipswich Methodist Church Organisation, and at the time of his death had been District Treasurer for general assessment for 30 years.

He was also a trustee of many local churches and of Central Hall, Westminster.

Mr. Hartley will be sadly missed not only as an outstanding engineer and administrator, but because of his kindly presence and rare personality, which created affection as well as respect in all his business and professional contacts. His passing is a grievous loss not only to the Institution, but to all who were privileged to know him.

INSTITUTION NOTES

August, 1948

NATIONAL COAL BOARD SCHOLARSHIPS The Institution has been asked to bring to the notice of members particulars of a scheme of scholarships offered by the National Coal Board.

The scheme aims at giving the best educational opportunities to (*a*) up to 50 boys of about 18 years of age, chosen directly from school; and (*b*) up to 50 young men already employed in the industry who are attending institutions for further education or can demonstrate their suitability in any other way.

Scholarships of the second type will cover the total cost of a university course, including maintenance allowances for vacations, and will also include marriage allowances if applicable. The Board will not lay down any specific academic standards for candidates for these scholarships, but they should, normally, be under 25 years of age, must have reached university entrance standard, whether for a degree or a diploma, and they will normally be expected to have followed a part-time course at a technical college or similar institution.

Full particulars and application forms for National Coal Board Scholarships may be obtained from the Director of Education, National Coal Board, Hobart House, Grosvenor Place, S.W.1.

MELBOURNE SECTION AWARD The Melbourne Section of the Institution has agreed to present an annual prize to the best student completing the full Production Engineering Course at the Melbourne Technical College. This is the foremost technical Institution in Australia, giving day and evening instruction to 17,000 students and correspondence courses to 15,000 students.

The Production Engineering School instructs advanced engineering students in production engineering, toolmaking, plastic die-making and technology, milling and gear cutting, fitting and turning. This department is recognised by the Education Department of Victoria as a centre for the advanced training of senior engineering apprentices.

The Melbourne Section prize, which is to the value of Three Guineas, will this year be presented to Mr. D. G. McWilliams, Stud.I.P.E.

COLLEGE OF AERONAUTICS The Board of Entry of the College invites applications from suitable candidates for the two year course commencing on 4th October, 1948. Candidates should be of graduate standard although the possession of a degree is not essential.

The curriculum covers Aerodynamics, Aircraft Design, Aircraft Propulsion, and Aircraft Production and Economics. Students who satisfactorily complete the course will receive the Diploma of the College.

Further particulars and details of the procedure for enrolment may be obtained on application to the Registrar, The College of Aeronautics, Cranfield, Bletchley, Bucks.

BRITISH INSTITUTE OF MANAGEMENT Mr. Austin Albu, B.Sc.(Eng.), M.I.P.E., A.M.I. Mech.E., has been appointed Deputy Director to the British Institute of Management, and is also in charge of the Information and Research Division.

Mr. Albu was educated at Tonbridge School and City and Guilds (Engineering) College. Having obtained practical experience in various engineering shops, including the shipyards of Armstrong-Whitworth at Newcastle-on-Tyne, he was appointed Technical Engineer at Electrolux, Ltd., Luton. From 1930 to 1945 he was Works Manager at Aladdin Industries, Ltd., Greenford, following which he joined the Control Commission as Deputy President of the Governmental Sub-Commission. Resigning from the Control Commission in 1947, he was appointed to his present post in February, 1948.

GRADUATESHIP EXAMINATION, 1948 The following candidates were successful in the 1948 Graduateship Examination of the Institution:

G. W. Adams, Stud.I.P.E., J. P. J. Anderson, A. A. Avery, W. F. A. Ayears, Miss P. M. Bailey, G. A. Blackshield, O. S. Brown, M. J. L. Butcher, Stud.I.P.E., E. Chapman, F. A. Cheshire, D. C. Clark, B. R. Cocks, T. J. Coote, Stud.I.P.E., I. D. Corbett, Stud.I.P.E., B. W. Cox, H. S. Cox, M. C. Cox, L. Craig-Brown, Stud.I.P.E., J. Critchley, G. R. T. Cummings, C. P. Davies, E. D. Dixon, N. Dooley, Miss E. D. Dunbar-Nasmith, J. J. Farley, C. Firth, J. Freel, D. V. Gallon, D. J. I. Gray, Stud.I.P.E., P. C. Grigg, A. G. Gulliver, B. P. Hague, J. A. Helps, Stud.I.P.E., B. Hill, F. Hinchey, W. E. Hipkiss, Stud.I.P.E., D. H. Horobin, E. G. Horton, F. Houghton, G. Houlsby, Stud.I.P.E., A. G. Inskipp, J. Jackson, Stud. I.P.E., A. A. Jacobsen, Stud.I.P.E., A. G. Jones, A. J. Kent, Stud.I.P.E., D. E. Kent, W. E. Knott, D. Lean, V. Lee-Brown, K. F. Lloyd, R. F. Loebl, A. G. Low, R. Lugg, P. A. McElwee, J. E. Mead, A. Milburn, D. Milburn, Stud.I.P.E., V. Mitchell, W. E. Mosse, D. W. Murray, E. C. Nicholson, W. H. E. Parr, G. Pateman, Stud.I.P.E., F. B. Pearce, J. M. Pearson, J. E. Pitchforth, Stud.I.P.E., T. Roberts, J. Robinson, R. S. Russell, J. E. Senior, Stud.I.P.E., R. Scott, Stud.I.P.E., R. T. Shackleton, B. Sharmall, K. Shield, P. E. Simmonds, A. F. W. Smith, E. Springthorpe, Stud.I.P.E., H. R. Stansfield, Stud.I.P.E., R. C. Taylor, W. Tindale, Stud.I.P.E., H. A. Turner, R. H Varcoe, G. C. Wadsworth, D. Wallace, L. Walmsley, N. H. Ward, J. Wardle, Stud.I.P.E., N. H. Watts, C. O. Webb, Stud.I.P.E., D. A. L. West, Stud.I.P.E., J. F. Westaway, G. R. Willcocks, Stud.I.P.E., L. Wix.

TECHNICAL EDUCATION The College of Aeronautics invites applications for the following posts in the Department of Aircraft Economics and Production: (*a*) Senior Lecturer in Production Engineering; (*b*) Senior Lecturer in Cost Accountancy and Production Control.

Candidates for (*a*) should be production engineers with a thorough knowledge of time and motion study, personnel management, wage incentives, etc. Additional qualifications would be experience in planning production control, and knowledge of industrial psychology and safety engineering would be an advantage. It is highly desirable that a considerable portion of this experience should have been gained in the aircraft industry. Preference would be given to a graduate with the equivalent of B.Sc. The selected applicant would be encouraged to study other related subjects, so as to extend his usefulness to the College, and to devote some time to research.

Candidates for (*b*) should have considerable experience of cost accounting and cost control, preferably in the aircraft industry. Additional qualifications would be experience in estimating, stores control and particularly in the application of punched card systems of industrial management.

The salary range for Senior Lecturers is between £600 and £1,000 p.a. according to qualifications, with superannuation under the Federated Superannuation System for Universities. Applications should be sent to the Registrar, The College of Aeronautics, Cranfield, Bletchley, Bucks, to be received not later than 23rd August, 1948.

INSTITUTION OF WORKS MANAGERS The Institution of Factory Managers and the Institution of Works Managers amalgamated on 1st July, 1948, the name of the new body being "Institution of Works Managers". The Registered Office of the Institution is 67/68, Chandos Place, London, W.C.2.

NEWS OF MEMBERS

Mr. F. P. Laurens, O.B.E., M.I.P.E., has been temporarily loaned by Vickers-Armstrongs, Ltd., to the Powers Accounting Machines Company, and has taken up duties there as Acting General Manager.

Mr. D. C. D. Anderson, A.M.I.P.E. (Sydney Section), has accepted an appointment as accountant with Hume Industries (Far East), Singapore.

Major A. C. Betterton, A.M.I.P.E., A.M.I.E.I., is now Circuit Manager with Anglo-American Oil Company, Ltd.

Mr. W. J. Denholm, A.M.I.P.E., is now Production Manager, Pressed Steel Co. Ltd., Linwood, Renfrewshire.

Mr. B. H. Dyson, M.I.P.E., has been appointed to the Board of Hoover (Washing Machines) Ltd., at Merthyr Tydfil.

Mr. G. E. Finch, A.M.I.P.E., has moved from B.O.A.C., Croydon, to B.O.A.C., Brentford, as Planning Engineer in charge of all home bases.

Mr. Percy E. Goodwin, Grad.I.P.E., Grad.I.Mech.E., A.I.I.A., has joined The General Engineering Company (Canada) Limited, as a member of the mechanical consultant staff.

Mr. F. N. Humphries, Grad.I.P.E., is now Assistant Works Manager at Kent Nail Works, Ltd., Edenbridge.

Mr. A. J. Lissaman, A.M.I.P.E., has taken an appointment at the North Gloucestershire Technical College, Cheltenham, as lecturer in Production Engineering.

Mr. R. V. Rider, Grad.I.P.E., has taken up the position of Efficiency Engineer with Durex Abrasives, Ltd., Birmingham.

Mr. H. M. Sawyer, A.M.I.Mech.E., A.M.I.P.E., has been appointed a Director of J. & F. Pool, Ltd., Hayle, Cornwall.

Mr. W. L. Todd, A.M.I.P.E., has been appointed to the post of Technical Officer by the Disabled Persons Employment Corporation, Ltd., Buckingham Gate, London.

Mr. A. C. Trubshaw, M.I.P.E., has taken an appointment as Manager of Messrs. A. C. Wickman, Ltd., Coventry.

Mr. T. C. Winmill, A.M.I.P.E., has recently been appointed to the Organisation and Methods Division, H.M. Treasury, as Organisation Officer.

HONOURS The Institution offers sincere congratulations to Mr. S. W. D. Lockwood, A.M.I.P.E., who was awarded the O.B.E. in the recent Birthday Honours List.

OBITUARY The Institution deeply regrets to announce the death of Mr. Innes Sinclair, M.B.E., M.I.P.E., of Coventry, Chief Engineer of Wild-Barfield Electric Furnaces, Ltd., Watford. Prior to joining this company, Mr. Sinclair was Assistant Manager of Alfred Herbert, Ltd., Coventry, with which firm he had spent many years.

In addition to his outstanding engineering ability, Mr. Sinclair was well-known both locally and nationally for his interest in fire brigade organisation and later in A.R.P. He had been Vice-President of the Coventry and District Associated Fire Brigades for over 25 years, and President for the last three years. His work for Civil Defence earned him the M.B.E. in 1943.

He was Vice-President of the Coventry Engineering Society and a prominent Freemason.

The Institution also announces, with great regret, the deaths of Mr. Charles Grew, M.I.P.E., of Birmingham Section ; Mr. James Rhodes, A.M.I.P.E., of Yorkshire Section ; and Mr. John F. Fraser, Int.A.M.I.P.E., of Shrewsbury Sub-Section.

BOOKS RECEIVED "The Workshop Yearbook & Production Engineering Manual," Part II. Edited by H. C. Town, M.I.Mech.E., M.I.P.E. Paul Elek, Ltd., Price 35/- net.

The second volume to be published with this title is, like its predecessor, a review of current Production Practice and Equipment, as well as being a general source of reference of firms who are engaged in supplying industry with its many requirements.

This book, however, covers a wider sphere than the first edition, but the two volumes may be considered as being complementary to each other—especially as the method of treatment follows the same pattern in both books.

The wide variety of subjects is treated in a comprehensive and up-to-date manner, and in the latter respect the chapter headed "The Application of Electronics to Machine Tools" will be of considerable interest to production engineers generally, in consideration of the extensive research that is in being on this subject.

The ever-growing application of the various discoveries in physics is well represented by articles on subjects such as industrial radiography, uses of the stroboscope in production technique, interferometers and other optical instruments, whilst in the chapter relating to the testing of materials, note was made of the photo-elastic methods of stress analysis, a system which although still in its infancy yet may have wide applications throughout the industry.

To those who found the first edition both useful and interesting, this second volume should prove to be a welcome addition, although the high price may put it out of reach of many who would benefit by it.

A.A.J.F., M.I.P.E.

"Hints on Steel." Published by Sanderson Brothers & Newbould, Ltd., Sheffield.

"Precision Hole Location." Machinery Publishing Co. Ltd., Brighton. Price £2 net.

ISSUE OF JOURNAL TO NEW MEMBERS Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

IMPORTANT In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

SECTION ACTIVITIES

BIRMINGHAM Arrangements are well advanced for the 1948/9 Syllabus, the majority of subjects chosen for discussion having application to " The Position of the Production Engineer in Relation to the National Economy ".

A special " Evening Conference " is being convened for Wednesda, 29th September, in the Chamber of Commerce Buildings, when Lt.-Col. L. Urwick will speak on " Education for Management ". Professor T. U. Matthew will be in the Chair, and will be supported by local industrialists. The Section Committee is aiming at an attendance of 300 senior industrial executives at this Conference.

The Section Social Committee is arranging for a minimum of six social functions next winter. The Section was well represented at the Wolverhampton P.M.H. Conference on 22nd May.

DERBY The Derby Sub-Section has completed a successful year of meetings, appreciation having been shown by the members with an average attendance of between 60 and 70 per meeting.

The Committee has finalised the lecture programme for the 1948/9 Session, and has in the main chosen specific production processes instead of favouring abstract subjects of higher management and control.

The membership of this Sub-Section is now 90—60 per cent. being junior members, and it was proved during last year's lectures that unspecific subjects do not appeal to junior members.

EASTERN COUNTIES The Section President, Mr. J. B. Webster, M.I.P.E., recently returned from a tour of Canada and the United States. During his trip Mr. Webster visited the manufacturing plants of Crane, Ltd., Montreal, Crane Coy, Chicago, and other industrial undertakings.

The lecture programme for 1948/9 is almost complete. The address by the Education Officer in October is awaited with interest, and a special invitation will be extended, on this occasion, to senior students of the Ipswich School of Technology. For the Common Subject chosen by the Institution, it is proposed to hold a discussion, with a prominent local industrialist to open the debate.

As on former occasions, the December lecture will be held at Colchester, and the guests will include members of the Colchester Engineering Society.

GLASGOW Three Works Visits have been arranged during the summer, to Hoover (Electric Motors) Ltd., Cambuslang; G. & J. Weir, Cathcart; and Anderson Boyes, Ltd., Motherwell.

The programme for next session has been completed, and covers a wide variety of subjects. In addition, there will be a special meeting when Mr. T. B. Worth will give a paper on " Education ", and there will also be two Informal Meetings during the Session.

HALIFAX The Annual General Meeting was held on Monday, 15th March, followed by a lecture on the 1946/7 Common Subject, " Various Aspects of Inspection and Production." This was very ably dealt with by one of the Section Committee members, Mr. B. McMahon. There was a good attendance of members and visitors, and all very were appreciative of an excellent paper.

Arrangements for the April lecture had to be cancelled at short notice, as the lecturer, Dr. Budgen, was detained in Canada.

On 5th May a visit was arranged to the works of Peglers, Ltd., Doncaster, which proved to be most instructive and interesting. On Saturday, 26th June, a visit was made to the School of Military Training, Ripon.

The new lecture programme is now completed, the Social Committee is actively engaged in preparations for next winter, and the General Committee meets regularly to deal with the business of the Section.

HALIFAX GRADUATE Two lectures and one Works Visit have been held, the Annual General Meeting being arranged to precede the second lecture. The Section Committee has met twice during the quarter.

On Monday, 5th April, at the Huddersfield Technical College, Messrs. W. Ogilvie and S. Ackrill gave their paper on " Multi-spindle Automatic Machines ". Mr. Ogilvie dealt briefly with the single spindle machine before passing on to the multispindle types. The lecture, which was well illustrated by lantern slides, was followed by a long and varied discussion, in which Mr. Ackrill answered the questions most lucidly, assisted on certain aspects by Mr. Ogilvie.

At the second Annual General Meeting on 1st May, the retiring Chairman, Mr. C. Squire, gave a résumé of the Section's activities during the past year. He referred to the growing Section membership, which now stood at a total of 74 Graduates and Students, and appealed to those present to do all they could to encourage members to attend lectures and visits.

The Section officials for the 1948/9 Session were elected, the Committee strength being raised to eight as suggested by the present Committee at their January meeting, and the duties of the Secretary split into two parts, viz., General and Meetings Secretary, and

Visits Secretary. A vote of thanks to Mr. Squire was passed, in appreciation of his services to the Section as Chairman since its inauguration in 1945.

The lecture which followed was given by Mr. L. H. Leedham, of the Ministry of Supply National Gas Turbine Establishment at Whetstone, Leicester. The subject was, "The Manufacture of Gas Turbines" and in the place of the advertised sound film, which for security reasons had to be omitted, a large number of lantern slides was shown. The ensuing discussion revealed a keen interest in this rapidly developing form of engine, and a hearty vote of thanks was passed to the lecturer.

On Friday, 23rd April, a visit was made to the steelworks of Samuel Fox & Co. Ltd., Stocksbridge, near Sheffield, where 27 members and guests spent a very interesting evening.

The Committee, at a meeting on 19th April, decided again to hold seven lectures and about four Works Visits, the lectures to be arranged—as last year—to take place on different week nights so as to allow evening class students to attend at least one. The Annual General Meeting is to be held on a Saturday in February, so as to comply with Head Office and Council requirements.

A special meeting of the Committee was called on 31st May to review the 1948/9 lecture programme position, which was by no means complete owing to the number of refusals received from prospective lecturers—mainly on account of pressure of work. Another list of suitable subjects was prepared.

LIVERPOOL Membership of the Section is now 113. Of particular interest to Liverpool members was the lecture on "Engineering Development at Speke—Aircraft to Rubber Production", given by Mr. D. J. Crabbe, Chief Engineer of the Dunlop Rubber Co. Ltd., Speke, on 24th March, and followed next day by a visit to the Works, where members were entertained to tea.

The Annual General Meeting wound up the Session on 21st April, and consisted of a short address by the Chairman, Mr. B. A. Williams, in which he most capably surveyed the problems and opportunities facing Production Engineers today.

On 17th September the new session will be opened as a full Section, with an Inaugural Meeting and Dinner. The principal speaker is to be the Rt. Hon. Harold Wilson, O.B.E., M.P., President of the Board of Trade, who will be supported by local industrial and educational personalities. Members of other Sections wishing to attend are invited to make early application for tickets (price one guinea) to the Hon. Secretary.

At the request of local members, a very full programme has been arranged for the coming session. Following the Inaugural Dinner in September, an Informal Discussion will be held for members only in the early part of October, followed in the same month by a

lecture, "Some Applications and Limitations of Plastics", by Mr. Walter Astle. The November lecture, "Wheels Behind The Wheels", supported by a film, will be of considerable value to engineers interested in manufacture and qualities of Grinding Wheels. Other interesting lectures arranged for the session include: "Metals in the Service of Man," by Dr. Alexander; "Education for Management," by Lt.-Col. L. Urwick, and "Difficulties and Developments in Deep Drawing and Pressing," by Dr. J. D. Jevons.

LONDON Four factory visits were held during the quarter, to India Rubber Gutta Percha Co. Ltd., Silvertown; Standard Motor Co. Ltd., Coventry; Kodak, Ltd., Harrow; and E.M.I. Factories, Ltd., Hayes. These visits were arranged with great care and the factories selected were chosen because of their special interest to members, with the result that the response was so great that a rationing system for applications has had to be devised.

The formation of a Reading Sub-Section having been approved by Council, arrangements are being made for a meeting to be held in London between the Section President and the Honorary Secretary, together with one or two members of the London Section Committee, and a number of members residing in the Reading area who are keenly interested in the formation of this sub-section. The purpose of the meeting is to devise a scheme for the setting up of the section, and to draw up a constitution with a view to ensuring that the sub-section is well set up right from the initial stages.

Tentative arrangements have been made to hold one lecture a month commencing in October. The programme that has been prepared is designed to provide a balance between the technical and managerial aspects of production engineering, and a great effort has been made to maintain a high standard.

At the suggestion of the Institute of Industrial Administration, a joint meeting was held on 1st July, when Mr. J. F. Lincoln of the Lincoln Electric Co., of America, gave a talk on "Incentives."

MANCHESTER The Annual General Meeting of the Section was held on Wednesday, 24th March, when Mr. H. G. Gregory was elected President for the second year. Following Section business, Mr. R. Whibley gave a most interesting paper on "Production of Flat Surfaces", dealing with the subject from an unusual angle.

It was with great regret that the Conference arranged for 17th April, on "National Production Needs—How They Can Be Met", had to be cancelled because of circumstances beyond the control of the Section.

On 21st April, the lecture was given by Mr. T. L. Gardner, whose

ubject was " Some Practical Aspects of Gas Turbines ". It was of unusual interest and there was a good discussion by a large audience. The visit to G. Richards & Co. Ltd., Broadheath, on 5th May, was very well attended, and was greatly enjoyed. Particular interest was taken in a 50 ft. Boring and Turning Mill in course of erection, as this is the largest mill ever made in this country.

The programme of lectures for 1948/9 is completed, and should prove very interesting.

NOTTINGHAM Since the last report, two Discussions have been held, in April and May. The subjects were " Inspection " and " Metal Finishing ", and both meetings were very well attended.

It is proposed to arrange two Works Visits during the summer months. Next Session, the meetings will follow the same lines as last year, when it is hoped to study in greater detail the subjects which formed the basis of these discussions.

Owing to the popularity of these Discussion Meetings, applications for membership have greatly increased, and the Section is looking forward with confidence to another successful session.

SHEFFIELD Both the March and April Meetings were unfortunately subjected to alteration. Mr. G. C. Chelioti was unable to be present on 17th March, and Mr. McGuire gave a very able address at short notice.

Just before 14th April, Mr. F. Parkinson was taken ill, and Mr. L. Godber, A.C.I.S., M.I.I.A., was persuaded to give a paper on "Job Evaluation—A New Approach to Salary Structure ". The members and visitors present were very interested in the system and a lengthy discussion ensued.

Prior to the reading of the paper a short address was given by the Pro-Vice-Chancellor of Sheffield University. The position with regard to intake of new students and the building and staffing problems attached to the demand for increased accommodation were outlined.

The last Informal Meeting of the Session was held on 24th March, but was poorly attended. The question of publicity for these useful gatherings is to be discussed at the local Committee Meeting.

SHREWSBURY Since the second Annual General Meeting of this Sub-Section, the Committee has met on two occasions. The main business has been the arrangement of the Lecture Programme, which has not yet been completed.

A number of interesting lectures and Works Visits have been held during the year, the average attendance at lecture meetings being over thirty.

Membership of the Sub-Section now stands at 44, and there are a number of applications under consideration.

SOUTH WALES AND MONMOUTHSHIRE

The Section's winter session concluded on 22nd April, with a lecture entitled, "British Production Methods". This dealt largely with P.E.R.A. and some very interesting lantern slides of the Association's activities were shown.

On 6th May, forty members and friends were guests of the Western Section, when a visit was paid to the Bristol Aeroplane Company and an interesting afternoon was spent in looking over the Brabazon Passenger Airliner and the Bristol Aero-engine Works. The visit was thoroughly enjoyed and it is hoped that a visit to some Works of similar interest can later be arranged with one of the other Sections.

On 29th May, the Section was privileged to return the compliment when a large party of members from the Western Section came to Cardiff, and looked over the Steelworks of Guest, Keen and Baldwin.

The Annual General Meeting was held on 28th May, when a past Secretary and active worker in the cause of the Institution, Mr. J. Vaughan, was unanimously elected President for the coming year.

The Committee expressed their satisfaction at the good response and attendance at all last Session's lectures, and is endeavouring to arrange for a varied and interesting series for next year.

WESTERN

Since the last report, the two final meetings of the last winter session were held, when Mr. G. Murray spoke on the "Cold Plastic Deformation of Metals" both in Bristol and Exeter.

The programme for the forthcoming session has now been completed, and has been compiled with the idea of covering as wide a range of subjects as possible and striking a reasonable balance between technical, practical and managerial topics. Six lecture meetings have been arranged for Bristol, and in addition, in view of the success of the scheme for taking lectures to other important towns within the Section, initiated last winter, it has been decided to hold meetings in Gloucester, Stroud, Exeter, Chippenham, and Swindon.

One good result of taking lectures to "provincial" towns is the subsequent interest in the Institution, which has materialised to the extent of increased membership.

The Committee has pursued the subject of Regional Co-operation, and there has been an exchange of visits with the South Wales and Monmouthshire Section, the latter visiting the Engine Division of the Bristol Aeroplane Co. Ltd., early in May. Later in the month, the Western Section paid a visit to Guest, Keen and Baldwin's Dowlais Works, where the whole process of steel production and section rolling was viewed. Both visits were judged to be an unqualified success and it was the general opinion of those par-

ticipating that, apart from the considerable interest value, the opportunity of meeting fellow members in other Sections was extremely valuable.

YORKSHIRE GRADUATE On 13th March, Mr. J. W. Poole, A.M.I.B.F., Grad.I.P.E., read his paper on "Principles and Practice of Metallurgical Testing and Research". This paper dealt with the fundamentals of testing and also gave examples of some of the latest developments in this sphere. The paper was particularly well received and a most interesting discussion followed.

On 17th April, Mr. R. J. Mitchell, M.I.Mech.E., M.I.E.E., read his paper, "The Relation of Research to Production Engineering". The paper was excellently delivered, and primarily for this reason was undoubtedly the best received paper of the Session. Mr. Mitchell dealt with a few classic examples of famous research work and their effects on production engineering.

A visit was made to the works of Messrs. Fred Smith (Wire Manufacturers) Ltd., on 26th April, which was exceptionally well conducted.

LORD AUSTIN PRIZE, 1948

Conditions of Award

(*a*) Graduates up to the age of 28 years are eligible to enter for the Lord Austin Prize, but may only be *awarded* the prize once during their term as Graduates.

(*b*) Closing date for entries will be 30th September, 1948. Essays should be sent to Head Office.

List of Subjects

1. Mechanical Handling.
2. Developments in Fine Measuring.
3. Application of Production Techniques to one non-engineering industry.
4. Work Measurement.
5. Economics of Jig and Tool Design.

Note : The attention of all Graduates is drawn to the article on page 397 of this issue, "The Planning of Technical Papers and Reports," by Mr. T. B. Worth, M.I.P.E., A.M.I.Mech.E., A.M.I.E.E., the Institution's Education Officer.

SECTION MEETING

September

14th BIRMINGHAM GRADUATE SECTION. A Film Evening has been arranged, dealing with "The Romance of Carborundum," to take place at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m.

THE PLANNING OF TECHNICAL PAPERS AND REPORTS

by T. B. WORTH, M.I.P.E., A.M.I.Mech.E., A.M.I.E.E.
Education Officer to the Institution.

"*Without forethought, there can be no precision.*"

It is an examination requirement of most professional bodies that candidates should be able to express themselves in writing clearly and concisely. However, apart from such requirements, the ability to produce well-balanced articles and reports is a most useful attribute of an engineer. There is, too, a wider aspect of this subject, as the criticism is often made that scientists, engineers and technicians have deficiencies in their powers of expression and that their articles, whilst being highly efficient in content, show little evidence of constructive ability.

After assessing the essays submitted for Institution prizes, it is apparent that this charge is not unfounded and that some guidance on this matter will be useful. These notes have been framed on those used in the teaching of Technical Report Writing, and it is hoped that they will prove useful to all intending authors of papers, although the notes have been prepared primarily for Graduates.

SURVEY A technical paper is essentially a product in which words form the raw material ; these are embodied in paragraphs which might be considered as sub-assemblies for final integration. Integration implies " a state of wholeness, unity and completeness, in which all the parts are in their right places, in a right relationship to one another and firmly compacted together." (H. T. Hamblin, Editor, *Science of Thought Review*). To achieve this, just as much forethought must be given to the planning of a paper as to the planning of an engineering project.

TITLE Too much importance cannot be attached to the selection of a title, which should indicate adequately the subject of the paper and, since there are many ways of treating the same subject, the title should also give some indication of the method of treatment. As an example, the title " Incentives " means little unless qualified, but " An Historical Survey of Engineering Incentives " is specific and leaves no doubt in the mind of the reader as to the method of treatment to be expected.

It is convenient to mention here that an author must always have in mind the type of reader for whom he is writing, though this is perhaps not so important in the case of technical papers presented to the Institution, whose members are technical and managerial.

TREATMENT To distinguish between the three usual types of paper, it is convenient to regard :—

(*a*) Technical Reports as " Specific "—distinctly objective and of limited scope.

(*b*) Technical Papers as " Expository "—bearing some relation to a report, but of wider scope.

(*c*) Essays as " Descriptive "—permitting of a less direct approach and allowing more digression.

Technical essays should be considered as technical papers rather than under the general term " essay ".

FORM All three types of paper follow a general pattern which may be represented by Fig. 1.

The links shown are important as is also the introduction or first paragraph. This should act as a focus and prepare the reader for what follows and, in some measure, it elaborates the title. It should contain, for instance, the subject, the reason for the paper, an idea of its scope and some reference to the general conclusion.

PLANNING Having decided on the title, scope and form of the paper, the planning should begin and this is best done by drawing up an outline in the form of a " tree " or chart. Sequence of ideas, however, is important and before assembling the chart it is convenient to make a list of the points to be covered. These will in the first place be in random order, showing no definition as to their location in Introduction, Body or Conclusion. This list of ideas should then be arranged according to location and each group graded according to importance. The chart may then be drawn and will follow the general pattern of Fig. 2.

EXECUTION With the above as a guide, the writer will find it not only easier to ensure that the exposition proceeds logically, but omissions and lack of reference will not occur. It gives, moreover, a logical approach which lessens the task but increases the pleasure.

USE OF HEADINGS Headings and sub-headings do not replace a carefully planned scheme of paragraphs, but they are of definite value in technical work since they act as dividers and pointers, making reference easier. Headings are best considered according to their importance and it is convenient to grant them " orders of importance ".

A First Order heading may be placed in the centre of the page and should be unencumbered by other matter.

A Second Order heading may be placed to the left of the page and should stand on a line of its own.

A Third Order heading may also be placed to the left, but is subordinate to a second order and does not require a separate line.

DIAGRAMS AND PHOTOGRAPHS In the past, papers submitted by Graduates for such awards as the Lord Austin Prize have shown a deficiency in the case of diagrams and photographs.

Whilst a management subject does not lend itself to the use of diagrams other than charts, most technical papers are enhanced by the inclusion of clear photographs and well-drawn diagrams. Where these occur, they should be so placed as to give ready reference whilst the related text is being read.

Too many photographs and diagrams are to be avoided and it is important that photographs should be chosen to illustrate adequately a point made in the text, and should not be included without reference.

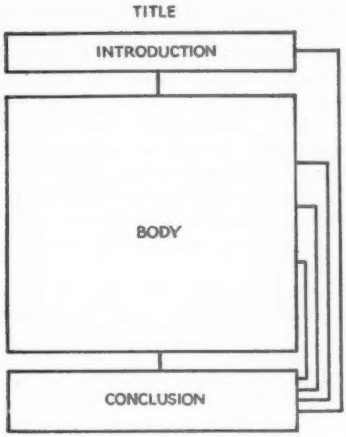
No matter how good the diagrams may be, they do not dispense with the necessity for planning the paper as a whole.

NOTATION AND FORMULAE It is often necessary to include symbols and formulae in technical papers and care must be used as to layout. A formula should stand in a certain amount of isolation, and a clear key should be provided to the symbols used, which should follow British Standard practice (*e.g.*, Engineering Symbols and Abbreviations).

BIBLIOGRAPHY If references are used, these should be acknowledged at the end of the paper. They make reference to the authority of a statement easier, are a source of further information and define the field covered in the preparation of the paper.

CONCLUSION Guidance such as is intended in these notes has been helpful in the past and by making it available through the Journal, it is hoped that it will not only be found helpful but will result in an increase in both the standard and number of papers submitted. Apart from any utilisation value, however, the planning of papers is a fascinating task provided it is approached logically, and it has a high educational content.

(*The figures referred to above appear on the following page*)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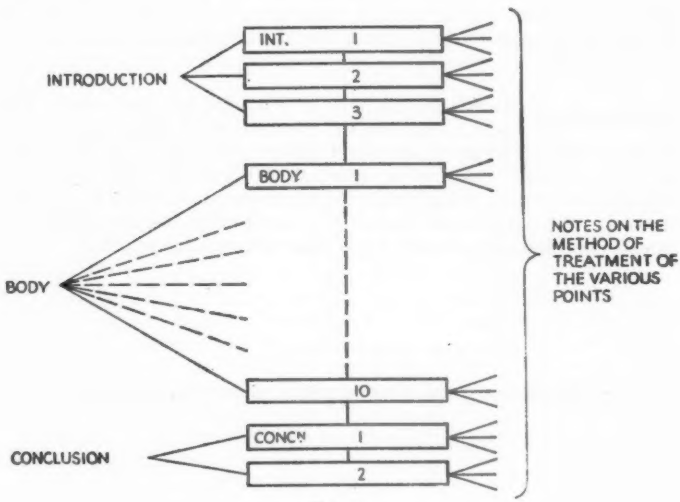
CONCLUSION

FIG. 1.


INT. 1
INTRODUCTION
2
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BODY
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CONC^N 1
CONCLUSION
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NOTES ON THE
METHOD OF
TREATMENT OF
THE VARIOUS
POINTS

FIG. 2.

ROLLING BEARING APPLICATIONS

by R. K. ALLAN, M.I.P.E., A.M.I.Mech.E.

Presented to the Manchester Section of the Institution, February 25th, 1948.

To members of an Institution devoted to the pursuit of economical production the subject of my talk may not immediately appear to be of very direct interest. It is contended, however, that anything which helps towards the manufacture of a better product, or the production of a greater number of parts in a given time, be it a mechanical device, a detail of procedure, or a new incentive, necessarily comes within our terms of reference.

Ball and Roller bearings come within this category, and are primary machine elements for which exaggerated claims were sometimes advanced in the past by incautious enthusiasts, but now that their qualities and capabilities are well understood they fall naturally into place as key units which are indispensable to modern engineering.

Quite a few practical aspects of the subject will be referred to, not for the purpose of demonstrating its complexity, but rather to show that the bearing characteristics should be in mechanical harmony with the functioning of the machine of which they are a part, and with associated details. To achieve that is no more difficult or troublesome than ensuring efficiency and economy by other means.

Ball and Roller bearing technology may be split up into quite a number of broad natural divisions, such as :—

History,
Theory,
Design,
Load Carrying Capacity,
Standardisation,
Manufacture,
The application of bearings to machines,
Limits and Fits,
Methods of Mounting,
Lubricants and Lubrication,
Maintenance,
Study of Failures.

Most of these divisions can be conveniently sub-divided. In particular, the application of bearings to machines should be separated into industrial groups, or groups of machines with similar characteristics, where special technique evolved to meet uncommon conditions of erection and operation is advantageous.

At a meeting of the London Section of the Institution on 14th November, 1946, it was my privilege to read a paper, "Some Observations on Rolling Bearing Technique" which was published in the Institution Journal for January, 1947. That had a theoretical bias, but the present one relates in a general way to matters of concern to those who build or service machines in which ball or roller bearings are an integral part, and may therefore be regarded as supplementary to the previous paper.

You will perhaps note the frequent use of the term "Rolling Bearings". This is the title given to my recent book on the subject since it is a term comprehensive enough to include every possible kind of bearing with rolling elements, is shorter than "ball and roller bearings" and makes it unnecessary to use the somewhat inappropriate term "anti-friction bearings".

Probably it is both true and fair to state that notwithstanding the extensive use of rolling bearings today, some misconceptions are still prevalent; the best application methods are not always fully understood or applied, and occasionally—possibly owing to some unfortunate but avoidable experience—confidence in the capabilities of these important machine elements is not too pronounced. To some extent such lapses from grace are understandable, for although rolling-bearing makers distribute technical literature freely, engineers perhaps have not the time, or think it unnecessary to study all the material about these specialised products that comes into their hands; they may not be disposed to accept every statement in such literature as gospel truth; or they may assume that much of the advice given is a counsel of perfection incapable of practical achievement.

Admittedly, the subject has its complexities, is of wide scope, and the makers apparently rather fussy at times about seemingly trivial details. Nevertheless, it is well to give heed to their advice, for it is based on extensive practical experience coupled with sound theoretical knowledge.

CHARACTERISTICS OF ROLLING BEARINGS

Bearing problems in relation to machine design are not here under review, and it is therefore assumed that the machine designer, preferably in co-operation with the bearing maker, has made the correct bearing selection to suit speed, load, and other peculiarities of the machine; that he has determined shaft and housing limits to give suitable fits; and that the protective devices for the bearings are adequate. Even so, everyone concerned with the fitting and maintenance of rolling bearings should be conversant with the main features of recognised standard types, together with related details. (Fig. 1.) (*This and subsequent illustrations appear on pages 422—432*).

Most rolling bearings are composed of one or more rows of

rolling elements—that is balls or rollers of through-hardened steel—assembled with a pair of through-hardened steel rings in which ground tracks of a particular shape are formed according to the shape of the rolling elements and the eventual function of the bearing. As a rule, the rolling elements are separated by means of a cage, the chief uses of which are to prevent adjacent rolling elements from rubbing together and to guide them through the bearings' unloaded zone. In separable bearings the cage also prevents the rolling elements from coming adrift. This is an important feature because steel balls in any one bearing should not vary in diameter by more than ·00005 in. for small sizes or ·0001 in. for large sizes ; since their group diameters in different bearings may differ considerably, the necessity of preventing rolling elements from one bearing mixing with those of another will be apparent.

Rolling bearings are generally classified in two main groups, namely radial and thrust types, although there is no clear line of demarcation between them. Radial bearings are designed for loads that are chiefly at right angles to the shaft axis, but many of these can take a proportion of axial load. Thrust bearings are designed for loads that are purely axial, but certain designs can accept a proportion of radial load.

The more usual types are indicated in Fig. 1. Each of these has several variants for specific purposes, and all are made in ranges of bore sizes and in series of varying sectional height and width, according to standardised external dimensions. Broadly speaking, designs A to E are classed as radial, H and I as thrust, and F and G as combined-duty bearings.

Possibly the most commonly used ball bearing is the " straight contact " type A. The term " straight contact " is derived from the fact that a line through the ball contacts is perpendicular to the shaft axis when pure radial load is applied. When thrust load is applied, the geometry of the design as well as the diametric slackness allows the rings to shift axially relative to each other, and a line through the contact points then makes an angle, as indicated by the dotted line, with a vertical plane through the bearing. From this, it follows that such a bearing cannot by itself locate a shaft axially with any great degree of precision. The bearing functions satisfactorily under radial, axial, or combined loads within its capacity. It is fairly rigid, and misalignment must therefore be avoided.

Type B is a similar bearing with two rows of balls and consequently more rigid than type A. Its load capacity is only 1½ times that of the single-row bearing, owing to the difficulty of ensuring that the load is shared equally by both rows.

The double row self-aligning ball bearing shown at C is of special value where misalignment of a few degrees, either permanent or variable, is unavoidable. Self-alignment is possible by virtue of

the spherical track in the outer ring. Because of the flattish curvature of the outer track, load capacity is reduced but this is compensated by the two rows of closely spaced balls, so that its actual capacity differs little from design A. It can carry combined loads in certain proportions.

The double row self-aligning roller bearing shown at E has similar functional characteristics to type C, together with very high load capacity—in fact it can take heavier loads than other types of the same dimensions. It is used extensively for heavy duty in steel-rolling mills, railway axleboxes, jaw crushers, rubber mixers, traction motors, and so on.

At D is indicated the well-known cylindrical-roller bearing with short rollers. The design shown can only carry pure radial load, but with a flange or flanges added to the inside of the outer ring, it becomes suitable for thrust loads, but this is limited by the effectiveness of lubrication between the thrust flanges and the roller ends. It must be mounted carefully owing to its sensitiveness to misalignment, but a design with one of the ring tracks made slightly convex minimises the sensitivity in this respect.

Bearings with long cylindrical rollers are less efficient, so that their field of usefulness is limited.

Needle roller bearings have long, small diameter rollers with no separating cage. A relatively large diametric slackness is necessary for reasonably efficient operation. They are most often used for low speeds, or where the rotary movement is oscillatory.

At G is shown the angular contact ball bearing, so-called because a line through the contact points lies at an angle to a perpendicular plane. The proportion of axial load that can be carried increases with the contact angle, and load capacity is relatively high owing to the number and size of the balls that can be fitted. It will be clear that axial load can only be taken in one direction, and that to prevent the rings moving apart when radial load is applied, an axial load is always necessary.

Double row bearings of this kind may have the lines through the contact points either converging inwardly or outwardly, the latter type being better for resisting tilting moments in certain cases.

At F is shown a single row angular-contact roller bearing, or taper-roller bearing as it is generally called. Its functional characteristics are similar to the ball type at G. A slightly convex outer ring track helps to avoid edge-loading of the rollers, and a sphered flange in conjunction with sphered big-ends of the rollers prevents skewing and reduces the friction coefficient.

At H is shown a single-thrust, and at I a double-thrust ball bearing. When correctly mounted these types are capable of ensuring very accurate axial shaft location.

BEARING LIFE

Like all other things in this world, the span of life of rolling bearings is determined by many factors. Some of these factors are not amenable to any rules, for their incidence is problematic, and their effects variable, about which more will be said later. Other factors *are* calculable within limits, and it is on a basis of these that tables of life expectancy are compiled.

Some manufacturers today—but not all—now give catalogue load ratings at different speeds for a given life, which are the outcome of extensive experience and innumerable tests backed by sound theoretical knowledge. These ratings are based on the fundamental fact that the number of revolutions a bearing can make before the first signs of fatigue appear on the tracks or rolling elements is inversely proportional to the cube of the load. For example, on completing one million revolutions, if a load of one ton has caused just perceptible fatigue, one-tenth of a ton would not have caused fatigue until 1,000 million revolutions. Dividing this by the r.p.m. gives the number of minutes, and dividing again by 60 gives the number of hours life. The basic theory is as simple as that. The rest is simple arithmetic, worked out and embodied in the comprehensive catalogue tables of the makers who use this realistic method.

What must be kept in mind, however, is that the fatigue properties of the steel from which the bearings are made vary to the extent that bearings of identical size and type carrying equal loads may have a life variation of 40 to 1, as shown by curve A, Fig. 2. (In fact, in the early days of the industry the life variation was about 200 to 1.) Continual research goes on in an endeavour to improve the steel and so reduce life variation, and the ratio may soon be brought down to 10 to 1 as indicated by curve B. Since the life variation must be taken into account, the load ratings are consequently based on a life expectancy that is greater than the minimum but much less than the maximum. Because of this, a small percentage of a large number of bearings may fail before the estimated life is reached, and a large percentage exceed it. The average life, therefore, is about four or five times that estimated.

This short reference to life expectancy has only been introduced to make it clear that rolling bearings are subject to laws which must be understood and applied for the sake of economy and efficiency.

LIMITS OF ACCURACY

Rolling bearings, like other machine-made products, are subject to dimensional and other variations, and the extent of departure from exactitude can be no less than the accuracy of the machine tools which produce them will allow. You will not need reminding that machine tools, even those in the precision class, can at times be perplexing in their

behaviour. Cutting tools may not be of exactly the right shape or kind, or lose their keenness in use ; slides and plain bearings are subject to wear, identical parts are not all gripped in a chuck in exactly the same way because of grit or ragged edges ; temperature varies, with resultant expansion and contraction effects ; and the gods of the machine, the setter and operator, like the machines themselves, have their limitations.

Some machines, of which machine tools are of special importance, require bearings of exceptional accuracy. Keeping in mind the points just mentioned, it becomes evident that greater bearing accuracy than that covered by normal standard specifications is only attainable at greatly increased cost. This is still more fully realised on consideration of the very many ways in which a rolling bearing has to be controlled.

All ring diameters are kept within close limits not only for size, but also for ovality and taper. Ring widths are within specified limits, and at the same time, the side faces are controlled for parallelism and squareness with the axis.

Grooves for the rolling elements must have the correct geometrical shape, have a minimum eccentricity, and a limited out-of-squareness with the axis. The outer diameter of inner rings and inner diameter of outer rings are closely controlled for diameter and concentricity when used for centring the cage.

In roller bearings, the flange surfaces which guide the roller ends are subject to close control for position, shape, and distance apart.

Cages for balls or rollers must be made with accuracy even when of pressed steel, or brass, or of moulded plastic material. Assembled bearings are also checked in various ways, apart from continuous running tests to destruction of a small proportion. Controlling any one of these items is easy, but keeping within the limits for all items in each and every bearing is a different matter.

In an up-to-date rolling bearing factory, every individual bearing is subjected to some 60 to 80 gauging operations, the complete inspection taking approximately one-third of the actual manufacturing time.

Before leaving this part of the subject, attention is drawn to the two recognised systems of nominal dimensions and limits. The British system (B.S.I.) covers both inch and metric sizes, and the International (I.S.A.) metric sizes only. With regard to metric bearing limits, the two systems are not in complete agreement, but correspond closely enough to make no real practical difference as to interchangeability in the majority of cases. The greatest differences apply to the large sizes of bearings where, fortunately,

perfect interchangeability is not usually of paramount importance. The limits for inch bearings differ considerably from the metric, and unfortunately were not very well conceived. It seems too late now to bring them into line with modern ideas.

Diagrammatic representation is perhaps the simplest way of showing these practical differences. Fig. 3 covers bearing bores and outside diameters up to 3 in. or 75 mm., the inch values being indicated by horizontal full lines, and the metric by dotted lines. In the upper left-hand diagram, it is seen that the tolerances for inch bores are bilateral and all of the same value up to 3 in., whereas the metric tolerances are unilateral with the nominal dimension as the upper limit and the tolerance increases in steps with the bore diameter. The upper right-hand diagram shows the kind of fit normally used for general engineering purposes. From 2 in. to 3 in. shaft diameter the extremes of fit are ·0002 in. and ·0012 in. interference ; that is, the fit tolerance is ·001 in. The top centre diagram shows the shaft limits necessary to achieve these interference fits, the inch and metric limits differing because of the difference between limits of the inch and metric bearing bores.

Limits and fits for bearing outer rings in their housings are similarly set out in the three lower diagrams. In these cases the clearances indicated at the right give a sliding fit.

To cover all the kinds of fit essential to ensure the satisfactory operation of rolling bearings in applications from scientific instruments to steel rolling mills, and wooden legs to battleships, requires about 15 grades of shaft limits and 13 grades of housing limits. Correct selection of the fit is almost as important as selection of the type and size of bearing ; therefore any departure from the limits specified by the designer may lead to trouble.

A loose fit under certain loading conditions may cause the ring to creep on its seating, which can result in cracks developing. Too light an interference fit initially may become a loose fit under heavy load or by differential expansion owing to temperature change. Conversely, a hard fit can cause overloading of the bearing unless it has extra initial internal slackness to allow for the inner ring expansion, or outer ring contraction due to the fit.

Depending on the dimensions of a bearing and the finish of the shaft and housing seatings, its inner ring will expand, or its outer ring contract, about 60 per cent. to 80 per cent. of the theoretical interference between them. That is to say, if the shaft seating is ·001 in. greater than the bearing bore, the initial slackness within the bearing will be reduced by about ·0007 in. That example will perhaps make it clear why the manufacturers prefer, except in special cases, to supply bearings with a certain amount of internal slackness.

Roller bearings require even more initial slackness because under load they yield less at the points of contact than the ball type.

Differential expansion of the rings due to temperature variation also affects the functioning of the bearing. An interesting example of this is railway axleboxes. It was found that owing to the increased rate of cooling of the outside of axleboxes at speeds above about 60 m.p.h., all slackness was taken up and hot running was the result. Increased initial slackness of the bearing provided an effective cure.

GAUGING BEARING SEATINGS

Rolling bearings have relatively thin rings, and are therefore easily distorted ; even the pressure of a gauge can cause sufficient change of shape to give a false measurement. From this it follows that the geometrical accuracy of shaft and housing seatings should be kept within well-defined limits ; otherwise the track diameter will vary from point to point and lead to unsatisfactory performance. Consequently, the gauging of the seatings is of some importance.

Only passing reference can be made here to gauging and gauging methods, but it may be said that gauges do not fulfil their purpose completely unless they infallibly reveal serious departures from true size and shape. Some gauges are so ill-designed or maintained that they are a menace to accurate work, and unfortunately some users have such blind faith in these measuring tools that neither their accuracy nor method of use is questioned sufficiently often. The temperature of gauge and work should of course be the same.

The high limit of an external cylindrical part is preferably checked by means of a ring gauge as at (*a*) in Fig. 4, this being the only method of ensuring that no part of the gauged surface lies outside the circumscribing circle of the gauge bore. Such gauges, however, are impracticable for various reasons, and snap gauges are generally employed. Both anvils of a snap gauge should make line contact with the surface, this being achieved in practice by making one anvil flat and long, and the other rounded and long, as shown at (*b*). Pointed anvils are apt to miss the high spots.

In checking the low limit, pointed anvils as at (*c*) are theoretically preferable because the object is to discover places below the general level of the surface. Since it is difficult to locate a diameter by means of two points, a flat anvil and a pointed one are used as at (*d*).

In a combination gauge as at (*e*) these principles are embodied by having a large flat anvil as base, with a long rounded anvil for the high limit, and a pointed one for the low limit.

As will be seen at (*a*) in Fig. 5, a low limit plug gauge when it

passes into a hole only informs us that no diameter is below that of the inscribed circle represented by the plug. This is the commonly adopted method of checking for minimum bore. For checking the maximum bore diameter, a pin gauge with pointed ends, as at (*b*), is necessary to seek out diameters that exceed the high limit. For practical reasons, the flat type of gauge as at (*c*) is often used.

The principle of a patented gauge is indicated at (*d*), from which it may be gathered that the gauging head is part of a sphere with a small raised button at one point. The sphere gives the low limit with line contact all round in any position if the hole is truly circular. The high limit is measured over the button when the gauge is tilted downwards, and the measurement is then between a line and a point. Any part of a through hole can be checked with this gauge, thus easily discovering ovality and taper as well as checking dimensional accuracy. The left-hand diagram indicates a hole that is too small since the gauge will not enter. The right-hand diagram shows a hole that is too large, since the high spot fails to make contact, and the gauge tilts right over. The middle diagram shows a correct bore, because the low limit spherical part has passed in, and the high spot makes contact when the gauge is slightly tilted. The pin-gauge at (*e*) is for large diameters, being pointed at one end, and with a large spherical part at the other end for stability in use.

MOUNTING FAULTS

Machine builders prefer to avoid future trouble by avoiding the cause, while maintenance engineers wish to know the cause when trouble arises. In so far as rolling bearings are concerned, there are many avoidable causes of unsatisfactory performance, but only a few can now be referred to.

As a general rule, there should only be one locating bearing on a shaft, all others being free to adjust their position laterally to accommodate expansion and contraction effects as well as machining and erection inaccuracies. An exception to this rule applies when a short shaft is supported by two bearings fairly close together as shown in Fig. 6. The correct mounting is indicated in the lower half of the drawing, where it is seen that the end cover spigots are just clear of the outer ring faces. In the upper half of the drawing, the end cover spigots are too long, with the result that when the covers are bolted up, the bearing rings are nipped together, thus applying heavy overload which will shorten the bearing life in proportion to the degree of nipping.

Although harmful when made use of injudiciously, clamping of the bearings is defensible under the name of " preloading ", for the bearings are then subjected to a known load prior to application of

the machine load, with the object of reducing relative axial and radial shaft movements to the minimum. The method is frequently adopted for spindle bearings in machine tools of the precision class.

Shaft shoulders should have the correct height. When the shoulder is too small its edge makes contact with the corner radius of the inner ring, and is therefore liable to cause distortion. Under thrust load the condition becomes worse. When an adequate shoulder cannot be formed directly on the shaft, a sleeve or specially shaped ring should be introduced. With all types of bearing taking thrust load, the rings should be well supported by the abutment shoulders. It is also important to ensure that the shaft fillet is smaller than the bearing corner radius.

The effects of slack fit on shaft or in housing have already been mentioned, and it is clear that when a shaft rotates it will creep round within the bearing bore in much the same way as a high ratio internal friction gear. Owing to compression at the point of contact between shaft and bearing bore, there may be considerable friction and wear, and it has been proved conclusively that pins, keys, and similar devices are useless to prevent the movement. Clamping by means of a nut is also useless, for the ring will continue to move radially under load unless the clamping pressure exceeds about 10 times the radial load, but it is practically impossible to achieve this.

Creep causes the hardened surface of the ring to pick up material from the unlubricated softer shaft surface, with the result that fine hair cracks develop and eventually cause ring fracture. The same effect is caused by dry rubbing between side faces and shaft shoulders. When the movement between the surfaces is minute, which may take place when two fitted surfaces do not make complete contact, finely divided particles are detached and become oxidised, thus forming the red rust known as "contact rust" or "fretting corrosion". Even in the absence of moisture the condition seems difficult to avoid, unless the fit is such as to eliminate all chance of strain and movement of the surfaces. No doubt most of you have observed this condition in other mating parts, such as shaft couplings, fixed pulleys, gear-wheel bosses, and so on.

A roughly finished seating surface may lead to creep, insufficient ring support, and distortion. Such surfaces are sometimes deliberately produced by means of punch marks in an effort to increase the diameter of an undersized shaft, and usually result in later trouble.

BEARING FAILURES

Having said this much about fitting faults, it is perhaps not inappropriate to give a little attention to bearing failures, since it is important that correct conclusions be drawn from them.

Most failures can be attributed to one or more of the following avoidable causes :—

1. Malformation of seatings.
2. Misalignment.
3. Faulty fitting.
4. Incorrect fits.
5. Inadequate, excessive or unsuitable lubrication.
6. Defective protection.
7. Vibration while the bearing is not rotating.
8. Passage of electric current through the bearing.
9. Defective material.
10. Errors in manufacture.

Needless to say, investigation of failures requires considerable knowledge and experience, so that the few cases about to be mentioned must only be regarded as isolated examples.

When the life of a rolling bearing is near its end, a minute patch of flaking appears on one of the tracks, as indicated by the arrow in the left view in Fig. 7. From the magnified view on the right, it is seen that the patch consists of a number of small pits in the track from which surface particles have broken away. This is typical of fatigue which may be due to a long running period under normal load, or a shorter period under heavy load.

From this incipient state, fatigue spreads until it may appear as in the single row ball bearing shown in Fig. 8. In the bearing on the left, the flaking is advanced but still localised, whereas in the one on the right, it has spread all round the ring.

At the left of Fig. 9 is seen the impression made by a piece of swarf which found its way between the housing seating and the outer ring of a cylindrical roller bearing. The local compression caused by the swarf set up a local high specific load and so produced the extensive flaked track area seen on the right.

Fretting corrosion of the O.D. is seen at the left of Fig. 10. At the right is shown the same ring with its track badly flaked owing to the resultant uneven load distribution.

If the washers of a thrust bearing are not strictly parallel with each other, or if the speed is too high in relation to the load imposed, spiral smearing marks occur as shown in Fig. 11. This spiral marking takes place when the balls are forced to move at a tangent to the track owing to centrifugal force in conjunction with light loading. This effect explains the modern preference for radial bearings for thrust loads when the speed is high.

Fig. 12 shows the advanced flaking resulting from edge-loading of the rollers due to misalignment of a taper roller bearing. To avoid this, the shaft and housing seatings must be strictly parallel, and abutment shoulders square to the axis.

Fig. 13 shows a thrust ball bearing and a needle roller bearing with deep marks produced by vibration while the machines in which they were fitted were standing idle. This kind of marking must not be confused with similar markings due to heavy blows. In the two cases shown, the " false Brinell effect " is really fretting corrosion, for small particles had been detached from the contact surface and immediately oxidised.

Methods of manufacture and inspection in the production of rolling bearings are now such that defects in the bearings themselves are of rare occurrence. For the sake of completeness, however, and to meet the possible criticism that the user is always blamed when trouble arises, three illustrations of manufacturing defects are included.

Fig. 14 shows two inner rings in which cracks have developed. Examination of the ring on the left made it clear that the cracks were caused by a slag inclusion in the material—an exceptionally rare defect. The curious formation of the cracks in the ring on the right also point to a flaw in the material.

The cluster of fine cracks seen in Fig. 15 were due to overheating of the ring in grinding and were revealed by etching.

Defective hardening is seldom a cause of failure, but when it is met, the surfaces acquire the porous appearance seen in the roller at the left, and in a ring at the right of Fig. 16.

LUBRICANTS AND LUBRICATION The fact that only a small amount of lubricant is required for a rolling bearing is perhaps responsible for the belief held by some that it is of little concern, and that any kind of grease or oil will do. On the contrary, lubrication is a highly developed branch of rolling bearing technique, and it is well to seek the advice of experts.

When running conditions permit, grease is generally preferable to oil, for it is easily handled and controlled and is an excellent protective medium. Lime-soap greases are generally suitable for bearings working in clean dry conditions, and where the working temperature is not outside the range 32-120 deg. F. They are insoluble in water, and are therefore to be avoided if there is any danger of moisture condensation in the housings during long stand-still periods. If such greases are melted they do not regain their original composition on cooling.

Soda-soap greases give good protection and can absorb a small proportion of moisture without materially affecting their lubricating value. Their temperature range is about 0-200 deg. F. If melted, they regain their original state when cool.

There are many brands of grease with widely varying characteristics and it pays to be sure that the right kind is used. If of too solid consistency it will retard the rotation of the rolling elements

with resultant skidding and heat. If of too light consistency, it will flow too readily into the bearing, and be churned up with consequent excessive temperature rise. The same effects result from the use of too much grease in a bearing housing.

Avoidance of grease churning is only possible by use of the correct grease, and ensuring that the quantity in the housing never exceeds a certain maximum—about two-thirds full is about right. There is also the question of replenishing the grease at intervals to make up for loss and deterioration. These intervals may be long or short as dictated by speed, load, temperature and other factors.

Such difficulties are overcome by means of the recently developed grease-escape valve, of which three types are shown in Fig. 17, as designed for electric motor bearings. A disc rotating with the shaft picks up excess grease and passes it through a narrow radial gap into a hollow space within the end cover. A wide opening in the bottom of the cover allows the superfluous grease to fall away into a suitable receptacle. Fresh grease is fed in close to the other side of the bearing, preferably while the bearing rotates, and therefore must pass through the bearing before reaching the grease-valve side. An important feature is the partitioning of the inside of the left-hand cover by means of radial webs. The webs prevent mass rotation of the main bulk of the grease there, and so prevent churning and rise of temperature. The valve only functions when the grease next to it is moving quickly, and normally this only occurs when the amount of grease in the housing is excessive.

Pure mineral oil is essential for certain working conditions, but this side of the subject is too extensive for treatment within the scope of this paper.

Oil-mist lubrication has recently been developed to an advanced stage, and is of special value for high speed grinding spindles and similar uses. The scheme greatly reduces the replacement of bearings in such cases, and also results in a great saving of oil.

TYPICAL ROLLING BEARING APPLICATIONS

Having outlined some matters of probable interest relating to the practical use and maintenance of rolling bearings, this paper may be completed by reference to several typical applications.

TEXTILE MACHINES

Having come to the hub of the cotton industry, it would be a serious omission to leave out any reference to textile machinery with its innumerable bearings, but there is only time to mention a few examples.

Without a doubt the most important unit is the spinning and twisting spindle, since there are some 200 million in use all over the world, with about 60 million in this country. Of the total, some 9 million plain bearing spindles are replaced annually. Little

imagination is therefore needed to appreciate the value attached to their efficient running, and to realise that fitting rolling bearings is a direct way of achieving that object. Because the so-called "flexible" or Rabbeth arrangement is necessary to permit spindle gyration, the rolling bearings type presented many problems, and it was not until about 22 years ago that a satisfactory design was evolved.

In one type of spindle for heavy spinning and twisting, damping of gyration is effected by means of oil in the base assisted by spring loaded friction surfaces. To enable the blade to be withdrawn in the same way as with the plain bearing spindles, there is an efficient plain conical footstep, and the rollers of the top roller bearing run direct on the hardened blade.

These roller bearing spindles show a power saving of up to 30 per cent., with the added virtues of uniform rotation, low oil-consumption, and cleanliness.

Weaving looms also figure largely in today's production drive, and it is not surprising that very determined efforts are now being made to bring them to a high standard of efficiency. The diagrammatic layout of an automatic loom shown in Fig. 18 indicates 30 points where ball-bearings can be fitted with advantage. Within the last few years in Sweden, about 260 looms have been so fitted with gratifying results. Trials on similar lines are proceeding in this country.

From the bearing point of view, the crankshaft is the most difficult owing to the necessity of threading the bearings over the cranks. Split bearings have not been a success, but a patented built-up crankshaft has solved this problem.

It is well known that treadle rollers with plain bearings are frequently responsible for outbreaks of fire, this being due to the difficulty of adequate lubrication. The rollers are somewhat inaccessible, and are only sparingly oiled to avoid contamination of yarn Sufficient heat is therefore often generated to ignite the fibres that collect round the roller.

A self-contained ball-bearing roller that only requires replenishing with grease once or twice a year by means of a grease gun has proved to be very successful.

PAPER-MAKING MACHINES

Another field for the extensive use of rolling bearings is paper-making, but as I have only a nodding acquaintance with this branch of engineering, my remarks are few.

In conjunction with the increased width and speeds of paper-making machines, rolling bearings have been adopted on an increasing scale, and they are now fitted at practically all positions of any consequence.

One problem peculiar to the wet end of a paper machine is the exclusion of water from the bearings, for the slightest rusting of the tracks and rolling elements brings the working life to an end with some rapidity. Of the many methods of sealing devised, the most elaborate have not always been the most successful. A correctly designed simple labyrinth is usually better than complicated stuffing boxes.

MACHINE TOOLS

For the quantity production of engineering components, the modern machine tool is the basic unit, and its work spindle the most important part. Accurate work is dependent on spindle rigidity, stability and concentric rotation under all conditions of load and speed, these qualities being largely governed by the spindle bearings.

Perhaps the most interesting bearing yet developed for machine tool spindles and the like is the double-row cylindrical roller bearing in which there are a large number of small diameter rollers giving a multiplicity of closely-spaced contact points. The section height is small, being only about 1 in. for a bearing of about 4 in. bore.

From Fig. 19, showing a bearing scheme incorporating the type of bearing just mentioned, it is seen that it is applied at the work end of the spindle, and has a taper bore to permit axial adjustment. By this means the inner ring can be expanded sufficiently to eliminate all radial slackness. The back end of the spindle is carried by an angular-contact ball bearing in conjunction with a single-thrust ball bearing ; these two are adjusted to eliminate axial play.

A spindle mounting using a double-row self-aligning roller bearing with its outer ring split circumferentially is shown in Fig. 20. The two halves of the split outer ring can be adjusted to eliminate all radial and axial play, and the adjustment is usually so contrived as to impose a predetermined initial load.

HEAVY DUTY BEARINGS

Rolling bearings are used for much heavier duties than is always realised, and for conditions in which safety is a most important factor. This is particularly so in the case of railway vehicles.

Many thousands of railway axleboxes with bearings fitted in the manner shown in Fig. 21 have been in service for long periods as well as other designs with only one bearing. Modern locomotives, passenger coaches, underground electric trains, goods waggons and high-speed rail cars have long since passed the experimental stage in so far as roller bearings are concerned. Bearing sizes range up to about 24 in. outside diameter, and loads up to about 20 tons per bearing.

Rubber mills use the same type of bearing where the load on each is up to 110 tons, and the saving in power obtained is about 40 per cent.

The double-row self-aligning roller bearing is also used for the largest rotary kiln in the world—in operation in this country. The load on the four pairs of supporting rollers is 480 tons.

A Lancashire mill 500 h.p. steam engine had a spherical roller bearing fitted to the connecting-rod big-end in 1921. Prior to this, $1\frac{1}{2}$ gallons of oil per day were required for the plain bearing but after converting to roller bearings only 1 pint of oil per week was necessary. At the same time, speed was increased from 64 to 70 r.p.m. and occasionally the output was increased to 750 h.p. According to the latest information it is still functioning.

Three thrust ball bearings $37\frac{1}{2}$ O.D. to take a load of 200 tons each at 30 r.p.m. were fitted to buffer-heading presses in Sheffield. After 25 years' continuous service they are still giving satisfaction.

STEEL MILLS

In the iron and steel industry much research was necessary during the development of suitable rolling bearing schemes, involving extensive study of operating conditions, devising apparatus for measuring loads, and the evolving of essential design formulae. Power saving in some rolling mills is as high as 60 per cent. Of perhaps equal importance to power saving is the ability to roll to finer limits than before, with a reduction of scrap, less wear and tear, and reduced maintenance costs.

A 20-ton flywheel with rope drive running at about 110 r.p.m. had roller bearings fitted in 1928, and the original bearings are still in use. One type of bearing arrangement used for 4-High Rolling Mills has an interesting feature—the loose mounting of the inner rings on the roll necks. This necessitates lubrication of the necks to prevent smearing due to creep.

Finally, a number of bearings with outside diameters up to 3 ft. 6 in. are in use in this country. The largest ones weigh $22\frac{1}{2}$ cwt. each, and carry about 700 tons on each pair of bearings per journal. They are on 4-High Rolling Mills for steel strip ; the rolls rotate at about 100 r.p.m. and the speed of rolling is about 1,500 ft. per minute.

This short survey of some aspects of rolling bearing practice may possibly have focused your attention on a few points worthy of notice regarding construction, peculiarities and possibilities While I am conscious of inadequate treatment of the subject, the main purpose will have been served if it has shown that a knowledge of the product, coupled with a reasonable amount of attention to detail in design, erection and maintenance is essential for efficiency and economy.

DISCUSSION

MR. MORTON : Mr. Allan, in his very interesting paper, said that lubrication by oil was a rather extensive subject which could not be dealt with in the time at his disposal. I should, however, like to tempt him to make comments on at least one or two aspects.

In bearings where oil lubrication is used, proper understanding of what is required of the lubricant is essential before a suitable choice can be made. The oil is called upon to lubricate the cage relative to the balls and also to the races, if it is a race located cage. It has to act as a coolant and it is also suggested that it may have beneficial action in reducing the stress concentration between ball and track by distributing the load. There seems to be some difference of opinion on that last point, and I shall be glad to have Mr. Allan's view.

With regard to cooling, it is stated generally that too much lubricant in the bearing is inadvisable as churning ensues, with resultant overheating. In that connection, first of all it is necessary to decide to what temperature a bearing may be expected to run with safety. I should like to put to Mr. Allan a suggestion that instead of using the minimum quantity of lubricant, it might be possible to go to the other extreme and have a lubricating arrangement whereby a very large quantity of oil indeed is passed through the bearing, the principle being that a point might be reached where the cooling of a large amount might completely outweigh any heating which may take place due to churning—particularly if the oil system is arranged so that the oil is fed in on one side of the bearing, has to pass right through, and then out at the other side.

Mr. Allan drew attention to oil-mist lubrication, which results in lubrication by oil and cooling by air. I should be interested to know the effectiveness of air cooling as I have not had any experience myself.

MR. ALLAN : Mr. Morton has put quite a good series of questions to begin the discussion—extremely pertinent questions. The first relates to the effect of load distribution between rolling elements and track. Everyone may not appreciate that the actual pressure in the contact area is of the order of 200 tons per square inch, and I think you will agree that under such pressure the oil can have very little effect on the load distribution, but it is admitted that the problem is not yet completely solved. The speed at which a ball or roller passes over a given point makes the contact almost instantaneous, and there is not time for the oil to be completely squeezed out. Assuming that some oil does remain in the contact area, load distribution is little affected because the fluid film is thin and simply transmits the pressure from rolling element to the track. The pressure area is either elliptical, circular or rectangular in shape, depending upon the kind of rolling element in the bearing. Pressure in the area affects the material immediately below the top skin and it is the stress in this region which causes flaking, rather than direct pressure on the upper layer. The action is quite complex and difficult to describe, but in brief, repetitive stress causes molecular change with consequent planes of weakness beneath the

surface, which eventually lead to rupture at the surface by the tensile stress at the edges of the pressure area. From this you will probably agree that an oil layer cannot have very much effect in counteracting fatigue.

With reference to the suggested use of a copious flow of oil, the quantity used must depend on conditions of speed, load, temperature, etc. Quite a number of applications use a circulatory oil system to carry away internal or external heat, the oil being passed through a cooling arrangement outside the housing. With too much lubricant—whether circulating or otherwise—excessive heat is generated by the work of the roller set in ploughing through the lubricant.

With regard to oil-mist lubrication, there are two methods in use. In one, the atomised oil is passed direct to the bearings, and I may mention the case of a number of grinding machines with ball-bearing spindles running at 30,000 r.p.m. Previously, with normal lubrication, the life was a few weeks. With the introduction of the oil-mist scheme using only a very small amount of oil, and with the cooling effect of the air, the bearings are still satisfactory after several months. One drawback is that the oil-mist gets into the atmosphere ; it is very minute in quantity, but is certainly noticeable.

The other method uses oil-mist produced as before, but by means of condensing nipples, the fine oil-mist is converted to minute drops which are carried into the bearing with the airstream. In this way, practically all of the oil goes to the bearing and none to the atmosphere.

Mr. Morton : What is the maximum working temperature which can be attained ?

Mr. Allan : That depends upon the tempering temperature of the steel—about 150 deg. C. Above that temperature, hardness and bearing capacity are reduced, *i.e.*, the material becomes less elastic and will not carry high stresses so well.

From a lubrication point of view, the permissible temperature depends on the lubricant itself. Lime-soap greases are suitable up to about 75 deg. F., and soda-soap greases to about 200 deg. F. Above that light or heavy mineral oil must be used according to working temperature.

Mr. J. Hayton : I would like to ask a question on lubrication. Many ball and roller bearings have no means of renewing the lubricant ; they are packed with grease when the machine is assembled, and this has to last until the next time the machine is dismantled—which may be years later. What does the lecturer think of that type, and how many years would it last without giving trouble ?

Mr. Allan : It is again a question of load, speed, temperature,

etc. You are probably referring to those originated in America, and called "Lubricated for Life" bearings. These are ordinary bearings with added side shields, and perhaps felt washers, and do not represent good practice. The lubricant deteriorates in time, but where conditions are not severe, the small amount in such bearings may last as long as required. There is no substitute, however, for routine lubrication. With lightly loaded bearings, clean conditions, and using grease as a lubricant, the normal replenishing period is one year, based on an eight-hour day. I have known cases, however, where the bearings have been put in and forgotten for several years, but working conditions were good.

Bearing makers must be cautious in making general statements, and could not justify unqualified advice to run bearings for several years without relubrication. In general, the amount of grease needed for replenishing and the number of working hours between lubrication periods can be determined, provided that the exact working conditions, speed, load, temperature, etc., are specified.

MR. GEJJI : There are one or two questions I would like to ask—first, could the lecturer tell me the difference between taper bearings as opposed to double-row cylindrical roller bearings ? And second, in view of the accepted suitability of the unilateral system, would you tell us why bearing manufacturers insist on the bilateral system ?

MR. ALLAN : The question of the bilateral tolerance used for inch bearings is not one that ball bearing manufacturers are anxious to re-open. I mentioned in my paper that it is a legacy of the past. At the beginning of the 1914/18 war, a need for standardisation was felt, and a Committee was set up which, without the extensive experience now available, adopted the limits now in use. If drastic changes were made now, bearing replacements would involve replacement of other parts.

In connection with double-row cylindrical roller bearings as compared with taper roller bearings for machine tool spindles, I do not propose to make a detailed comparison between them because the firm I am with can supply either. Personally I prefer the double-row type, because it has a multiplicity of bearing points giving a more rigid support for the spindle, and there is no undulation of stress round the rings as obtained with larger and fewer rollers. The taper roller bearing in itself is quite good if accurately made, but has a higher co-efficient of friction, and presents problems in manufacture because not only diameter and angles have to be considered, but also the location of each roller in exact relation to the thrust flange. With only two taper roller bearings on the spindle—one at the back and one at the work end—difficulties arise owing to expansion and contraction.

Mr. Allan was then asked if he could give the particular reason for the design of the high speed cage as opposed to a medium speed

one, which is centred on the inner race. If located on balls or rollers, did this cause more friction between the cage and rollers than when located on the inner race?

Mr. Allan: The designs developed for high speed are the result of experiment rather than theoretical consideration. As far as load is concerned, a cage would have to be very badly out of centre to develop any great centrifugal effect. With a solid cage, the normal practice is to centre it on the lands of the inner ring, but I have seen many such bearings with the cage worn in the bore. This is probably due to faulty lubrication at this point. Locating the cage on the lands of the outer ring is also used, the theory being that centrifugal force throws oil in that direction. My own view is that for a ball bearing a cage located on the balls is the most satisfactory. It is a question of ensuring that the contact areas are well lubricated, and avoiding dry rubbing on the lands as occurs with the other designs. Another way is to make use of plastics. I am at present interested in certain experiments proceeding on these lines, but finality has not yet been reached. Plastic cages are quite good, but have a very much higher co-efficient of expansion than steel, and designers must keep that fact in mind.

Mr. Murphy: Could you tell me whether the design of taper roller bearings is so perfect that it prevents "slip" taking place? Is there any tendency for the roller to twist?

Mr. Allan: Presumably you are referring to roller misalignment. If the roller has a flat end, then there are only two points of contact with the flange, and any force tending to turn the roller out of its true axis is resisted by the reaction at these points. In some designs there is only a single central point of contact; that is bad, because the roller must then be controlled by less direct means. With the design having the roller end and the flange thrust surface sphered, there is full area of contact so that the tendency of the rollers to skew is completely resisted in the most direct and efficient way. All rollers should bear against the flange and be held there under load. With that condition satisfied, then skewing is prevented. My firm makes the ends of rollers and flange surface as described.

Mr. Cranmer: When Mr. Allan referred to the failure of rolling bearings due to vibration, my mind went back to the recent talk which Mr. Windeler gave to us on "mechanical mishaps", when he stated that when a number of electric motors were sent abroad, failure occurred almost immediately after starting up. After very considerable investigation, he came to the conclusion that the trouble was caused by vibration during transit, *i.e.*, either on the lorry from the works to the docks, on the ship, or during transport at the other end, because the bearings showed a definite hammering on the lower side only, which was apparently due to vibration of the

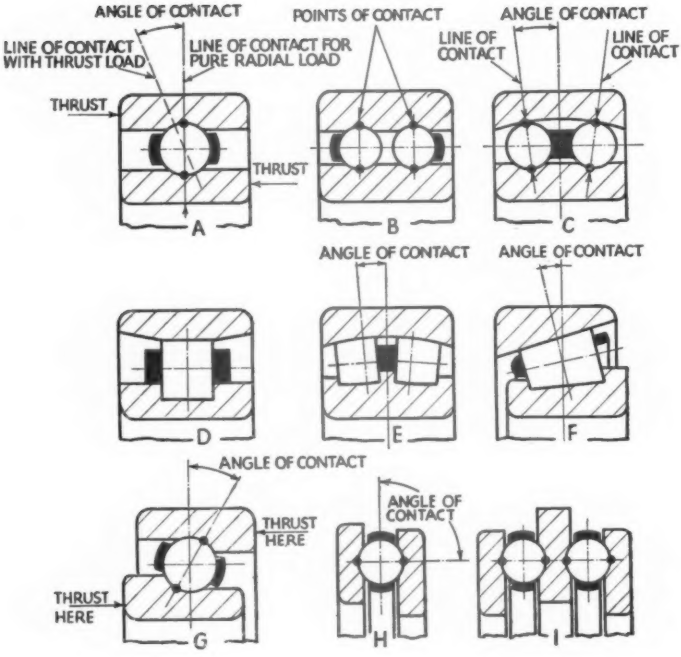
rotor. Mr. Windeler stated that all such electrical equipment which they send abroad at present has to be dismantled and the rotor packed separately, and no complaints have been received in this direction since this method was adopted. Perhaps Mr. Allan will give us his view on this theory.

Mr. Allan : Vibration set up while a machine is stationary, and in particular during transport, is a frequent cause of indentation of bearing tracks, and the cases referred to provide further evidence that suitable precautions must be taken to prevent relative movement, either by dismantling as mentioned, or by wedging the parts.

In a paper read before the American Society of Mechanical Engineers in 1937, Mr. J. O. Almen gave the detailed results of an investigation into this problem. He came to the conclusion that the markings on the bearing tracks were not pressure indentations, but a form of fretting corrosion, and the effect is therefore sometimes referred to as " False Brinelling ". The wear was reduced, but not eliminated by the use of low-viscosity lubricants.

A comprehensive paper on " Fretting Corrosion and Fatigue Strength ", not specifically related to rolling bearings, will be found in the November 1941 Journal of the Institution of Mechanical Engineers.

Mr. Gregory : We have had a very interesting paper from Mr. Allan, and I think that I am expressing the opinion of the Manchester Section when I say that this is one of the most interesting papers we have had, and we do appreciate Mr. Allan giving his time to preparing and presenting the paper to us.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LINE OF CONTACT FOR PURE RADIAL LOAD
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THRUST
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LINE OF CONTACT
LINE OF CONTACT
C
D
ANGLE OF CONTACT
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THRUST HERE
THRUST HERE
G
ANGLE OF CONTACT
H
I

FIG. 1.

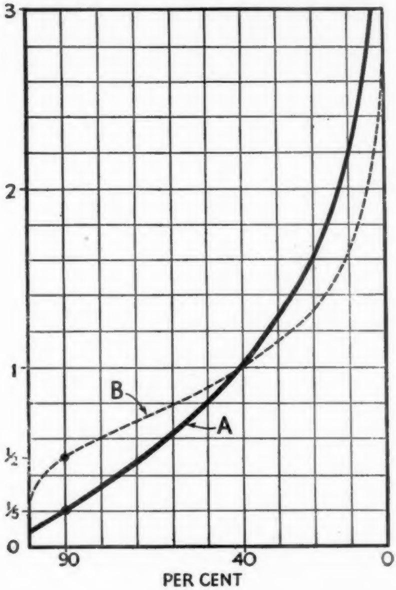
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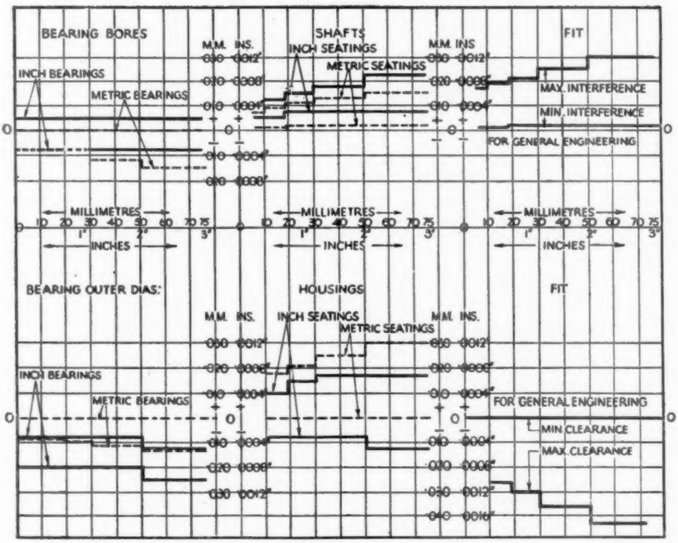
Fig. 2.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INCH BEARINGS
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SHAFTS
INCH SEATINGS
METRIC SEATINGS
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MIN. CLEARANCE
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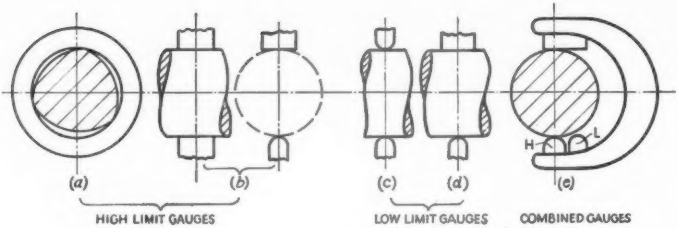
Fig. 3.



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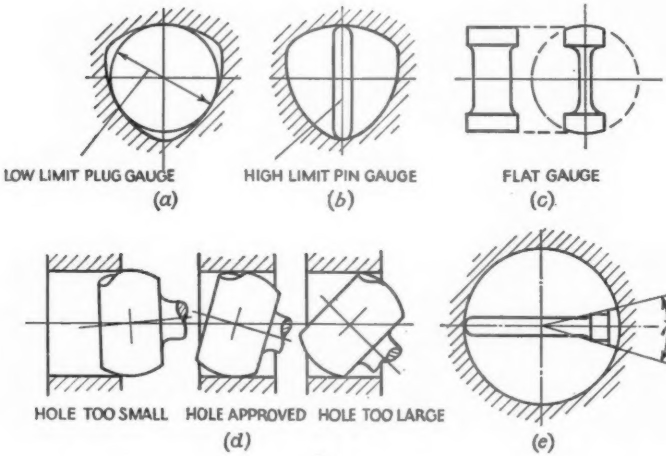

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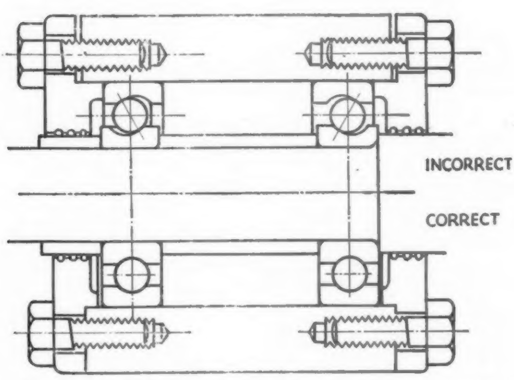


FIG. 6. Excessive axial load due to cross location. *Result* : early fatigue.

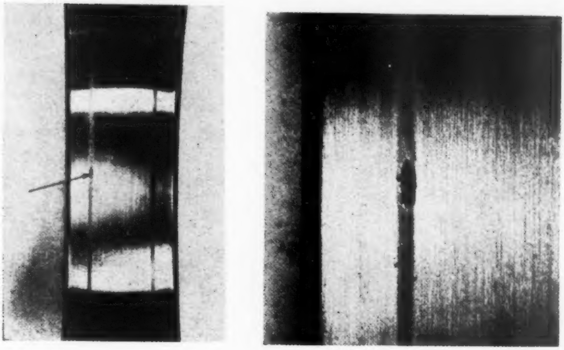


FIG. 7.

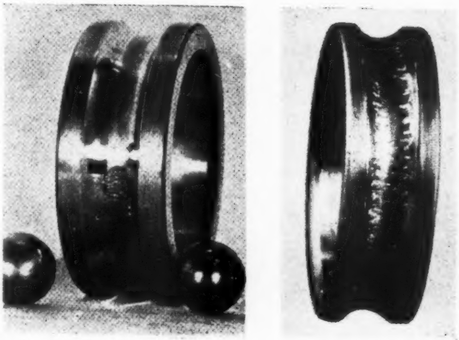


FIG. 8.

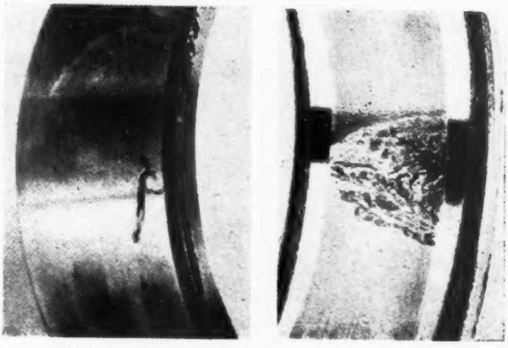
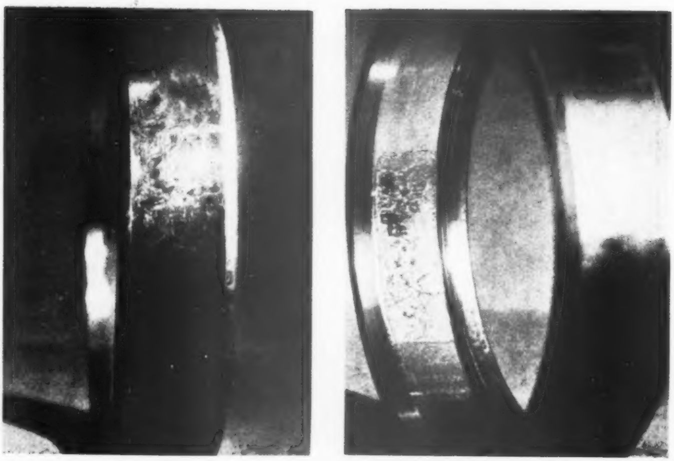


FIG. 9.



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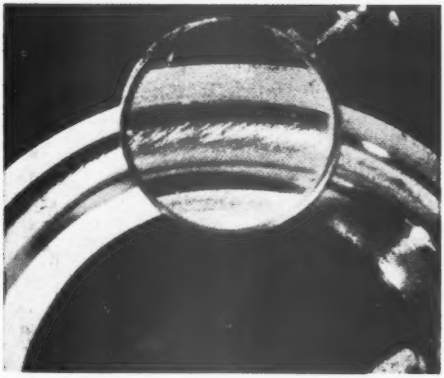
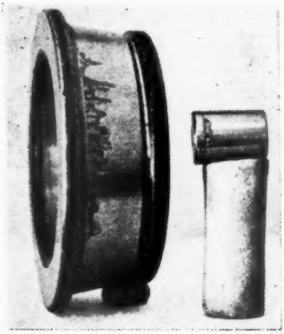


Fig. 11.



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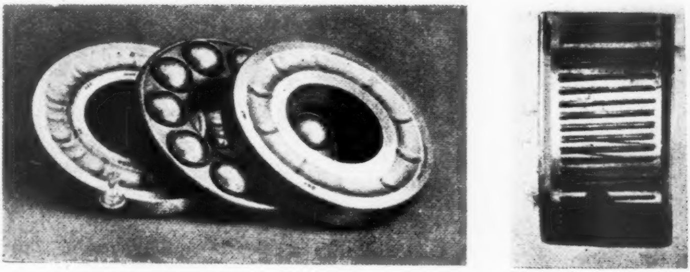

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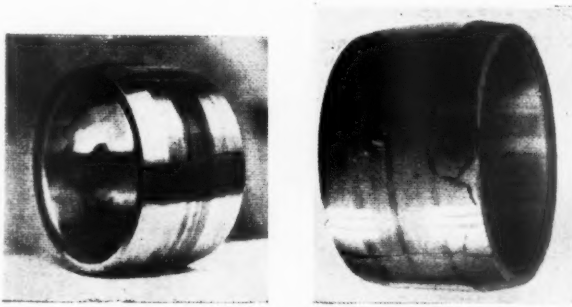
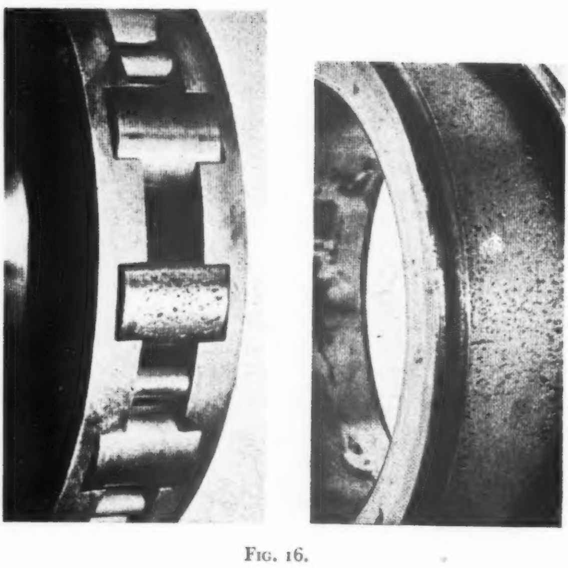


FIG. 14.

Fig. 15.



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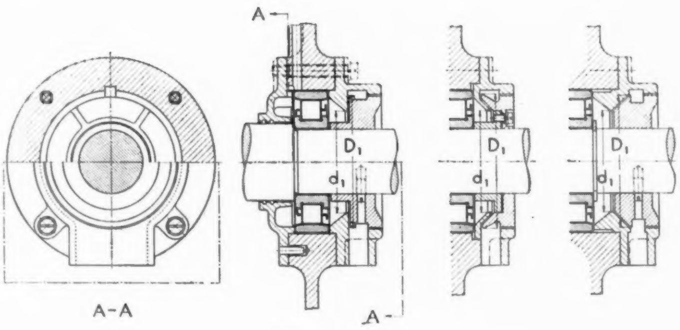

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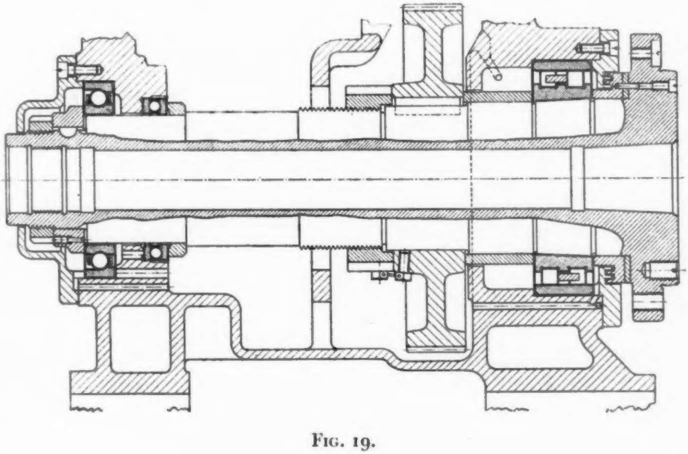

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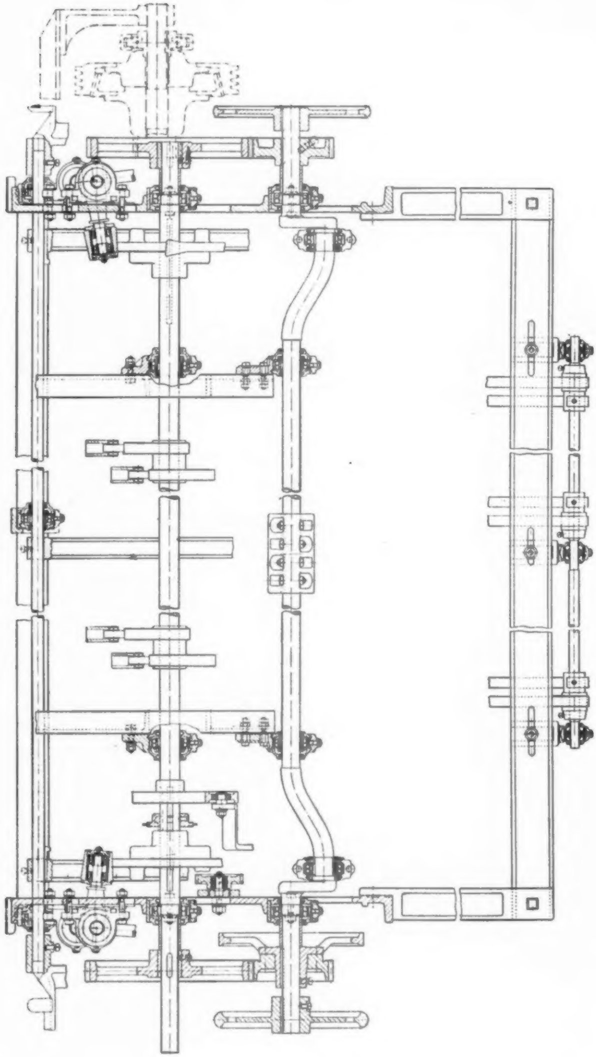
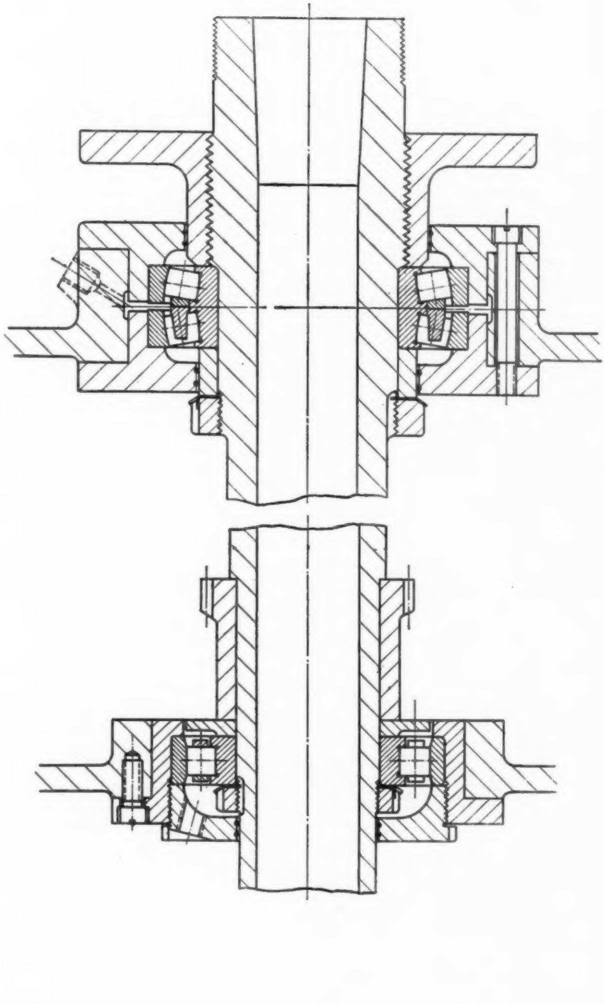


Fig. 18.



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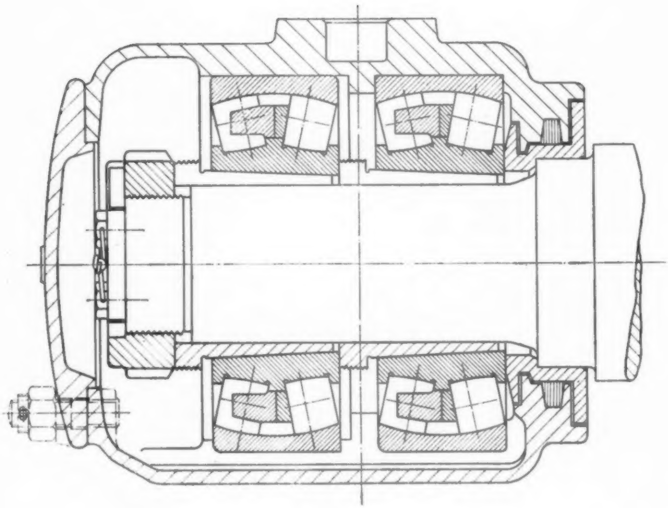

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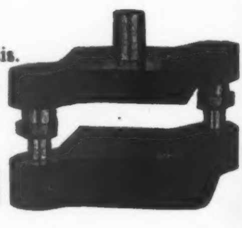

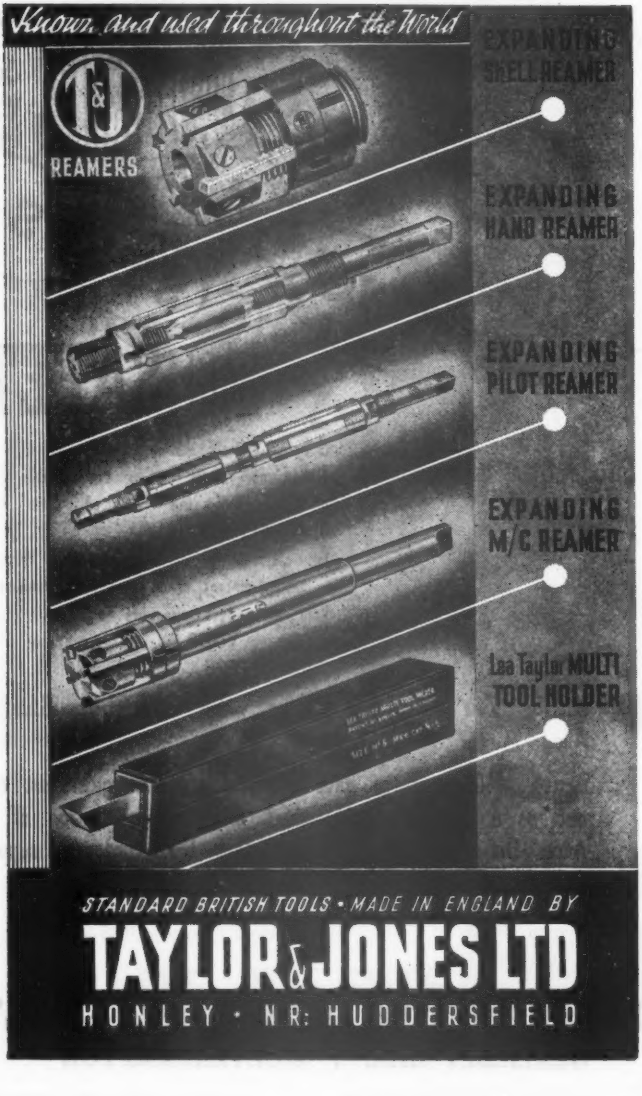
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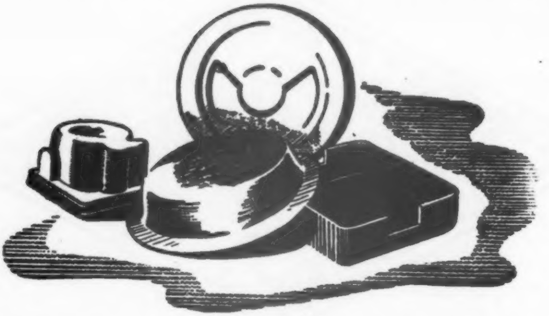

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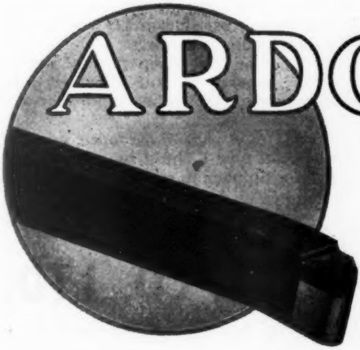

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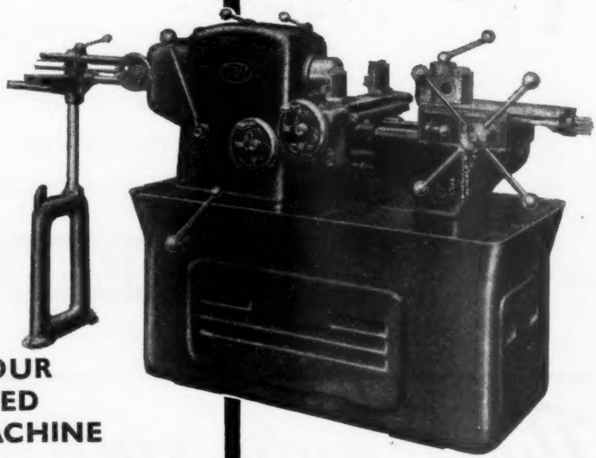

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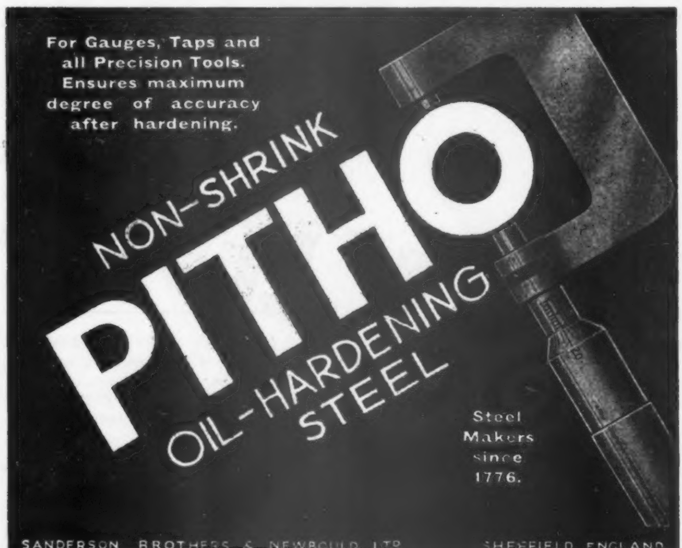
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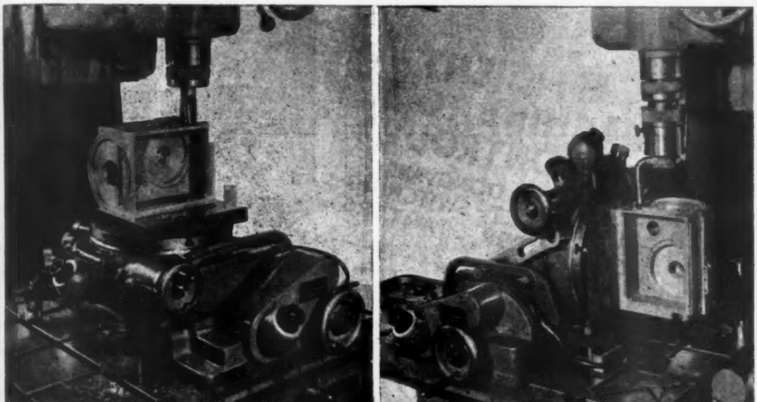

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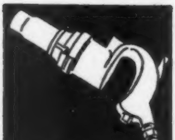

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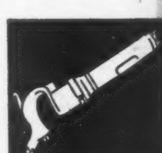

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